Design of Vital Sign Monitor based on Wireless Sensor Networks and Telemedicine Technology

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Abstract— **Heart attack is a term generally used for medical conditions like Acute Myocardial Infarction, Cardiac Arrest, and Atrial Fibrillation. Before the onset of such an abnormal condition, there are symptoms which generally we avoid to care. Even after the attack the patient needs continuous monitoring and care. But all this needs to be at a very affordable cost, thus developing a Quality, Secured and Cost effective health monitoring system becomes the need of the hour.**

The Proposed Vital Sign Monitor is based on a wireless sensor network and telemedicine technology. This system is designed to be a mini patient monitoring system which measures the vital parameters like ECG, Heart Rate and Respiration Rate. The system uses Bluetooth technology which is embedded with the sensor for faster transmission. The transmitter unit is designed to be an Android based smart phone through an application that connects to wireless networks using the best source of connectivity which is either a 3G network or IEEE 802.11 i.e. Wi-Fi based transmission. The proposed system implements the IEEE 1073 standard for medical device communication. The remote system consists of a cloud server where the centralized monitoring takes place. The expert in the remote center can view all the patient data and at the same time can witness full duplex real time streaming video if required, so that the expert can take a confident call. If required the expert can ask the individual in the spot to take indispensable action and in critical cases can accelerate an ambulance for attending the emergency case.

The power utilized by the entire system is low due to the intelligent algorithms that control the system. The principles of green computing and signal processing applied in the system help in the development of a green smart system. The vital sign monitor designed can improve the reach and affordability of healthcare in developing countries affected by various socioeconomic crises.

***Index Terms*—Telemedicine, Vital Sign Monitor, Green Computing, Smart System, Wireless Sensor Networks, Healthcare.**

I. INTRODUCTION

Telemedicine is providing the healthcare services and knowledge sharing of trends in medicine and latest research across distant locations through various communication channels and media. A telemedicine system provides solutions to health care woes virtually and helps making the health care delivery faster, affordable and reaches the mass. Telemedicine is not something very new and is being constantly developed with the development of various new technologies in allied fields of electronics, communication, engineering design, materials etc. The principle of Telemedicine is in existence for about 3 decades now through the use of various modern telecommunication technologies [1]. Today, systems used for telemedicine are based on state of the art Technologies like Satellites, High Speed Networks, Interactive TV, high resolution monitors, and telecommunications superhighways including fiber optics, switching systems and cellular telephony [2, 12. 13].

Coronary artery diseases are a coarse model of high death rates in remote or monitoring cases for most patients die before getting to the hospital. In a study performed, it is an unfortunate fact that patient more than 50 years who die from cardiac arrest, 91% do so before going into the hospital [3, 4, 14]. The availability of medical attention at any given instant can not merely serve the patient, but at the same time improves the QoS of health care delivery. In emergency cases where handling needs to be almost instantaneous, early and specialized pre-hospital patient management helps in patient's survival [3, 4]. The reduction in high mortality rates can be attained by proper preparation, accurate strategies and clever measures; this method would not merely improve the approach to health care, but also administration of quality wellness care and monitoring services [5, 15].

One of the most important Telemedicine application field is home monitoring. The numbers of patients being admitted to hospitals are increasing, but in countries like India, the patient-bed ratio is not increasing at the same pace, thus arises the demand of home monitoring and then the patients can avail the quality service quickly and at affordable prices. Using good tele-video equipment through various advanced communication means would reduce the frequency of visits to clinics or hospitals thereby saving time and exertions. In summation, these days we can connect various diagnostic devices to the telemedicine system, hence affording an opportunity to the clinicians and patients to interact with real-time information and virtual presence, which enables in maintaining the patient-doctor rapport and also raise security levels can enable high confidentiality of the data. For example, vital signs can be broadcast over the web so that the doctor can view the medical condition of the patients at the

same time with real time video being transmitted at the both end the patient every bit well as doctors can keep communicating and try to diagnose and treat the ill condition.

Many telemetry systems with different technological approaches have been introduced over the years, but even so there are many topics that have not been broken up and hamper the spread of this tremendous technology in real-time treatment. Recent development, communication domain and IT infrastructure has enhanced the capability of computing and intelligence which could be again used to make the telemedicine technology more friendly, affordable and more importantly improve the cattle farm of quality health services around the world.

II. System Description

The Vital Sign Monitor is based on a wireless sensor network and telemedicine technology. This system is a mini patient monitoring system which measures the vital parameters ECG, Heart Rate and Respiration Rate. The scheme would be an All in One (AIO) wireless system using Bluetooth technology, which is implanted with the sensing element for faster transmission. The transmitter unit will be an Android based smart phone through an application that links up to wireless networks employing the best source of connectivity which is either a 3G network or IEEE 802.11 i.e. Wi-Fi based transmission.

The device implements the IEEE 1073 standard for medical device communication from the system calls for the medical data transmission. Further, the expert in the remote telemedicine center can view all the patient data and at the same time can witness full duplex real time streaming video if required, so that the expert can use up a confident claim. If needed the expert can ask the mortal in the spotlight to take indispensable action and in critical cases can accelerate an ambulance for attending the emergency event. This entire arrangement can be used personally or also be installed in public amenities for its efficient function. It can as well be carried to ambulances easily.

The scheme can also play as an AHM i.e. Anytime Health Monitor just like an ATM (Automated Teller Machine) with all exam results being mailed to the concerned doctor. Since this is a Wireless Diagnostic Device which involves patient data and health, the FDA standards for medical devices will be followed and also HIPAA Act for information security will be complied, so arriving at the system secured and cost efficient. The following measures are carried out in the entire Vital Sign Monitor system:

- IEEE 802.11 – WLAN protocol for wireless information transfer through mobile connectivity thus will help in wireless data transfer [6].
- IEEE 1073 – The system involves medical data transmission between wireless sensors and Android based transmitting unit and further across through a fixed network, thus, IEEE 1073 standard for medical device communication will be implemented to have a secured data over the network [7].
- FDA – Being a medical device the safety is a prime focus and hence US FDA (Federal Drug and Administration) Standards are complied thus making it suitable to practice with patients. The gimmick will have special safety controls and electrically insulated to avoid any kind of micro or macro shocks [8].
- HIPAA – The information security is another prime focus and hence data security will be taken care based on the regulations governed by HIPAA (Health Insurance Portability and Accountability Act) compliances [9, 10].

III. Vital Sign Monitor

The Vital Sign Monitor mainly comprises of the following:

- Acquisition
- Transmission
- Server Validation and Processing
- Emergency Data Forward to specialist

The ECG, Heart Rate and Respiration Rate are acquired using the sensing hardware. The acquisition hardware consists of specialized integrated circuits like ADS1292R, INA 101, and UAF42 etc. The data is transmitted to an android based Smartphone through Bluetooth. The android application to send the information securely to the server works as a data forwarder and viewer. Through Wide Area Network or Virtual Private Network or Intra hospital network the data are beamed to the Remote server. The remote server hosts the application to compile the data and monitor. The tele-consultant in the server can forward the data to the specialist if an emergency comes up. The doctor can view the secured data through the specialist Android application and if necessary can establish a link with the patient at once. The overall block diagram of the Vital Sign Monitor is shown in Fig 1.

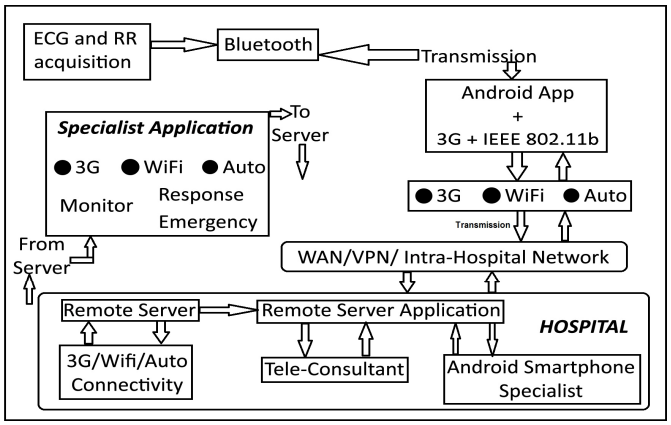

Fig.1 Overall Block Diagram of Vital Sign Monitor

The individual block of the system can be described as follows:

- Acquisition: The data acquisition is through integrated circuits using INA 101, ADS1292R, MSP430 Microcontrollers, and UAF42.
- Bluetooth: The wireless channel which transmits data from the sensor to the system.

- Patient Application: It's the specialized android based patient application which acts as the display to the vital monitor system and also the medium of transmitting data to the server.
- Communication Channel: A secured communication is established through VPN (Virtual Private Network) or WAN (Wide Area Network) or Intra hospital networks.
- Server Application: The server system houses the LabVIEW based application, which acquires and analyzes the information been obtained from the patient. The heart rate variability analysis of the data is additionally carried out since the monitoring period is very long. The Server application also carries out the operation to select the mode of communication and also establish a secured link with the patient.
- Tele-Consultant Application: The tele-consultant gives an overlook to the incoming data and in case of emergency guides the patient.
- Specialist Application: The specialist application provides all the necessary functions for the doctor to appear through the medical information of the patient and at the same time constitute the connection with the patient if required.

The block diagram of the hardware for Vital Sign Monitor system is presented in Fig. 2

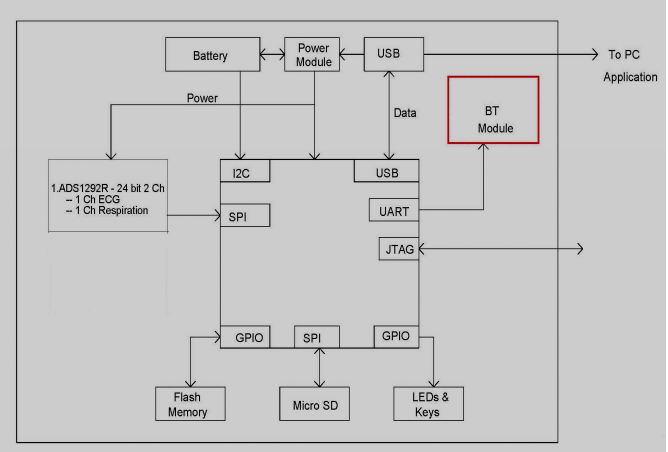

Fig. 2 Hardware – Vital Sign Monitor

IV. Design of Vital Sign Monitor

The entire design of the system is modularized for easier development of the entire system. The system design calls for the consolidation of several playing areas of Electronics, Communication, Information Technology, Mobile Computing and Engineering Design.

The data are first sent to the Mobile Application using Bluetooth and then further through the use of smart algorithms for mobile application compresses the information and forwards it to the computer application in the host. Wherever the mobile application is missing the data transmission could go through the personal data processor or laptop of the patients. In real time this transmitted data will contain the Analog waveform and digital values of Heart Rate and Respiration Rate.

The mobile communication module consists of the android module for managing transmission and receipt of data through Bluetooth [11]. The android application performs the following operations:

- Searches for devices, and displays the signal intensity.
- Use Serial communication for data transmission.
- The resultant data is saved to the memory.

Fig. 3 shows the Android application developed which further consists of the following modules:

- N Mode: Basic I/O
- K Mode: User interactive mode for advanced users.
- C Mode: For Debugging and Service.

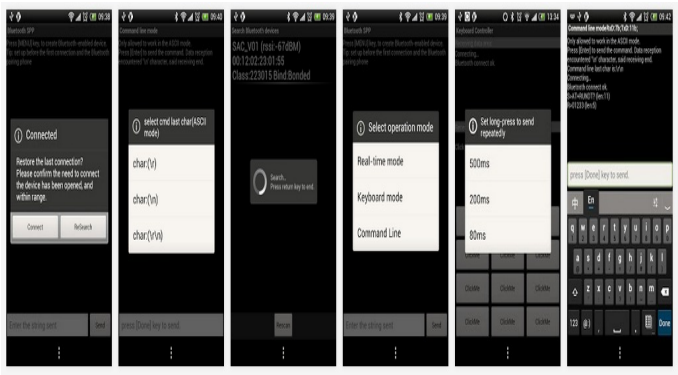

Fig. 3 Bluetooth Serial Profile Android Application

The heart rate monitor application is installed on a dedicated server for multiple connections to transmit data through the network and displayed in one screen or multiple screens. Fig. 4 shows the heart rate monitor application. This would be a central monitor where all the patient data are displayed in terms of heart rate.

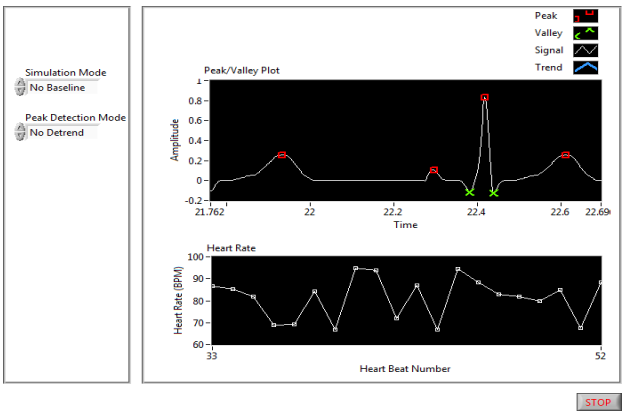

Fig. 4 Heart Rate Monitor Application for Server

Compression is the next important aspect of the vital monitor. A large amount of data is received at the server as

well as on the mobile device; hence the memory requirements will be too large. Also, if needed the tele-consultant forwards the data to the specialist hence compression technique is preferred. The Compression is performed using Wavelet DB-2 filter. The compression program for the web server is developed using the GUI interface of LabVIEW. Fig. 5 shows the compressed ECG data in the server application.

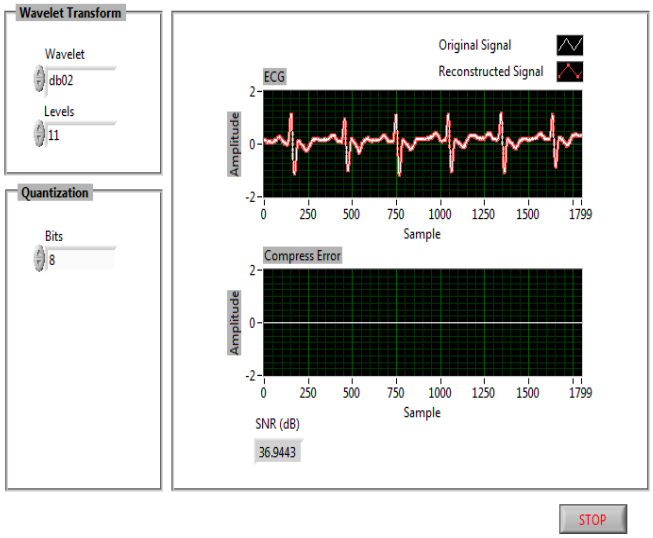

Fig. 5 ECG Compression in the server application

The Data reception through multiple channels is equally crucial in the system design. The algorithm for the reception is again designed using LabVIEW. This application looks through the reception of data from the network and loads it to the server. The Data Packet Receiver application is shown in Fig. 6

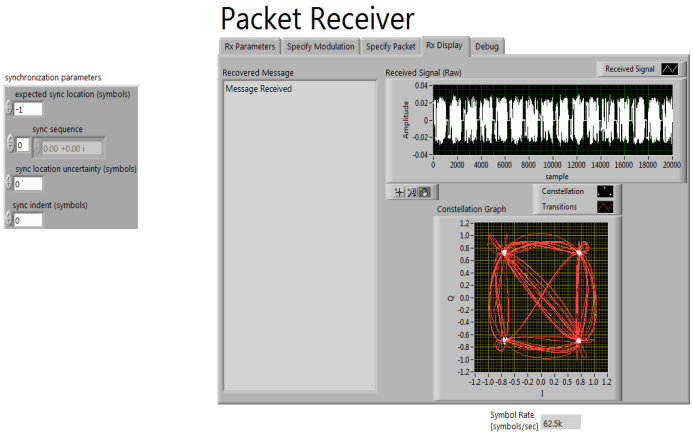

Fig. 6 Data Packet Receiver application

The data transmission from the server to the expert system or application is the most important communication channel designed. This application looks through the transmission of data from the server to the network and loads it to the client node. The packet transmission application is shown in the Fig. 7

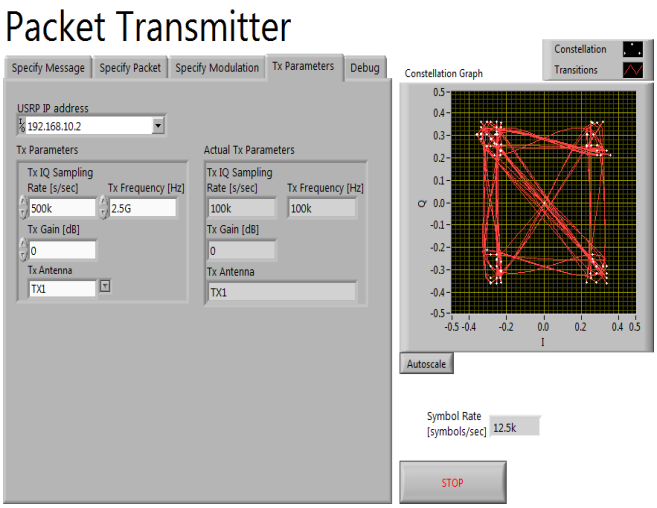

Fig. 7 Packet Transmission Server application

The heart rate variability analysis helps in realizing the movement of the heart function, therefore enabling a safe diagnostic tool to the physician. The HRV analysis tool is embedded within the server application.

Hardware design of the vital monitor system mainly evolves around the microcontroller and the smart algorithm which would aid in achieving low power consumption and at the same time.

V. Discussion

The various algorithms used in the discussed application which are designed so far revolve around the principles of Green Computing, Green Electronics and Green Communication. The hardware design which is in progress uses green electronic components that are lead free thus would be easy to discard or reuse. The various algorithms designed for the applications so far follow the software optimization and deployment optimization principle. The algorithms are smart and can likewise be modified into intelligent algorithms, thereby facilitating self optimization.

The major feature of the Vital Sign Monitor is the blueprint for high power efficiency and thereby optimizing the power consumption, which helps in longer battery life and thus better utilization of the arrangement. The algorithms used in both the controller as well as the applications give an emphasis on optimized resource allocation which enables the system to be energy efficient without compromising on the performance of data processing and communication.

The server applications designed are for the cloud server, thus bringing in the virtualization principle to the system which again takes the system towards green computing. The design of the system is it hardware or the software points towards green technologies, thus making up a telemedicine system keeping in mind of the environment and the future.

The total design is modularized which enables the possibility of system updates with the pace of developing technology. The entire system integration and design have been carried out keeping in mind the cost effectiveness and green engineering, thus paving up the style for an affordable and environmentally friendly application of telemedicine for the betterment of health maintenance.

The system design and development is under progress, but the initial results and evolution has been as expected and is in line towards development of a system which could not only ameliorate the health care services but also towards building a healthy and smart company.

VI. Conclusion

The Vital Sign Monitor involves the implementation of the principles of the wireless sensor and the telemedicine network. The project involves development of the hardware for data acquisition, Server application for remote monitoring, android application for patient and android application for the specialist.

The integrated system will form the Vital Sign monitor for telemedicine based monitoring. The design and development of the following modules are completed.

- Transmission of data from MCU to Bluetooth
- Bluetooth serial port profile for android
- Heart rate monitor for server application
- ECG compression for server application
- Server Data Reception Using LabVIEW
- Server Data Transmission Using LabVIEW
- Data Flow Control Application in Server
- Heart Rate Variability Application (Server)

The individual application gives expected output and the integration of the application will be done once the network connectivity and other allied applications are developed.

This system is an attempt to develop a Quality, Secured and Cost effective health monitoring system to improve the health care solutions and enhance the reach of medicine even in the remote locations where health care is inaccessible. By such an attempt to save patients we can not only save a life, but an entire family which is contingent on the patient.

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