A Bluetooth Enabled Personal Health Monitoring System Using Android Device

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***Abstract*—Measurements of vital signs and behavioral patterns can be translated into accurate predictions of health risk. The proposed system suggests an anytime anywhere health monitoring mechanism via an application providing heart monitoring data through easy-to-use interfaces. Using this savior and chronically ill patient's measure their heart readings and can send to their respective clinical assistant who can analyze this data remotely and prescribe accordingly. Proposed system is based on Bluetooth wireless protocol supporting good quality medical sensors, as well as wireless transport for access to faster and reliable communication network resources. Efficient and capable heart monitoring sensors senses the heart beats and sends to gateway using Bluetooth, calculation and process performed by embedded microcontroller. Android based smart phone device acting as a mobile gateway running the application, and forward data to remote clinical server to which physician is connected.**

***Index Terms*—Remote Patient Monitoring system, Bluetooth, Wireless Body Area Network, m-Healthcare, Android**

I. INTRODUCTION

In the past few years a new paradigm in medical information technology has been introduced. It is known as wireless body area network which is part of wireless sensor technology. The development of wireless sensor network has got lots of attention from researchers due to self-organized, self-optimized and fault tolerance nature of it. As the world population ages, those suffering from chronic diseases will increase and respectively the cost for health care will increase. Transparently embedded remote health care can become a new cost effective paradigm, which can solve most of the problems primarily centralized Health Care system's have.

Provision of ubiquitous healthcare solutions anytime anywhere continues to be a major challenge, with an ever increasing need for efficient remote healthcare systems. In such a position wireless connectivity has emerged as an alternative of fixed network. It opens new avenues which are not restricted to cellular communication.[3] As consider the advantages of e-healthcare system is, important for maintain case history records, continuous patient monitoring, medical prescriptions and receiving patient feedbacks. With the aging population and complex physiological situation personal continuous health monitoring is often desired. That's why a new remote health monitoring m-healthcare system in demand.

Remotely mobile-based healthcare services allow patients full mobility at their homes, where health-care providers can monitor their health data remotely. Such mobile-based connected healthcare systems besides reducing the waiting time for face-to-face contact with physicians, are capable of generating alerts being sent to the patients on their mobile phone based on sensor readings. Such healthcare systems can be useful for the elderly and terminally ill patients confined within their homes, or for working or travelling parents to deliver quality healthcare to their infants.[2] The user's interface and data communication represent important issues for healthcare systems. The last evolutions in the pervasive computing area (new smart phone running Symbian OS, Windows Mobile, Android OS, iOS) enable the possibility to develop new graphical interfaces that can be easily used to perform tasks such as clinical and sensor data management, smart sensor data exchange, and alarm generation.[1] According to the Global Mobile Health Market Report 2010-2015 compiled by research2guidance, more than a third of 1.4 billion Smartphone users in 2015 are estimated to be running some kind of mobile application for healthcare systems. However, these systems face continuous challenges in reliability, inter-operability with different body sensor devices, and scalability. In some systems, XML formatted SMS are transmitted from handheld device used by patient to the server and to doctor, related people and database.

This paper presents a Bluetooth based wireless body area network for medical m-health system which acquire the data from bio medical sensors of physiological parameters like ECG, EEG, Heart Beat, Glucose meter, Blood Pressure. Sensors are wearable on body and sense the human body different parameters, these sensed data to be processed and computed by the efficient microcontroller. Microcontroller generates the packets of reading and sends to the Bluetooth for forward to the android based gateway. Android based gateway get the readings, process and display them and forward to the clinical assistant or doctor by SMS or send to clinical website by the use of internet connectivity.

Android is an open source platform, currently supported by a wide range of devices. Applications for Android devices are hardware independent and need not to be digitally signed or preinstalled by the manufacturer on the devices regarding to use core device's resources, like network access, SMS sending etc. Android is a very favorable platform for building custom applications summarized platform features are [4]

- Advanced UI with touch-driven interaction

- Portability
- Exposed APIs for Bluetooth radio access
- Unrestrained hardware access through unified APIs to access the different services
- Multi homing over Wi-Fi or cellular network (2G/3G)
- Unprecedented security and application permission management policy

II. Related Work

The m-healthcare applications are being developed using embedded platforms which range from smart phones to wireless sensor nodes which enable physical, physiological and cognitive / behavioral studies. A number of research groups in leading universities are rapidly developing prototype solutions using WSN. Some of those are as briefly listed in the following: [3][5][7]

Code blue is a Harvard University project focusing on wireless sensor network development for medical applications. Their project uses an integrated sensing of medical data e.g. ECG (Electrocardiography), SP02 (Oxygen Saturation measurement), Pulse rate and EMG (Electromyography) and communicate to a server through wireless motes.

MIThril is a project to study human behavior, it is developed by MIT media Lab for wearable medical platform to measure ECG, skin temperature, Galvanic Skin Response (GSR) along with data for step and gait analysis [7].

Medicon uses wireless backbone network using Relay Points (RP) instead of ad hoc network or Bluetooth. It reduces routing overheads.

Alarm-Net is used for pervasive, adaptive e-healthcare at home which addresses the requirement of aging population requiring proactive monitoring for early detection of abnormalities and maintaining a medical therapy / exercise schedule through alerts [5].

Prototype intelligent homes have been built at many research institutes and universities to test the concepts and make suitable products to have continuous monitoring of aging and seriously ill or disabled persons. Intel Research Seattle and University of Washington have built a system to monitor daily living activities. University of Rochester is building a smart home; Georgia Tech has built an Aware Home and MIT is working on "Place Lab" initiative.

III. Design and Implementation

Health monitoring system is the application of wireless sensor technology. Wireless body area network is the type of wireless sensor network which is limited to communicate around human body. WBAN has specific defined architecture is shown in fig.1 based on that the entire m-health system works. Different WBAN protocols are defined to communicate with gateway and further communication performed by the cellular network or IEEE 802.11 standards. Here presented block diagram of the wireless body area network architecture.

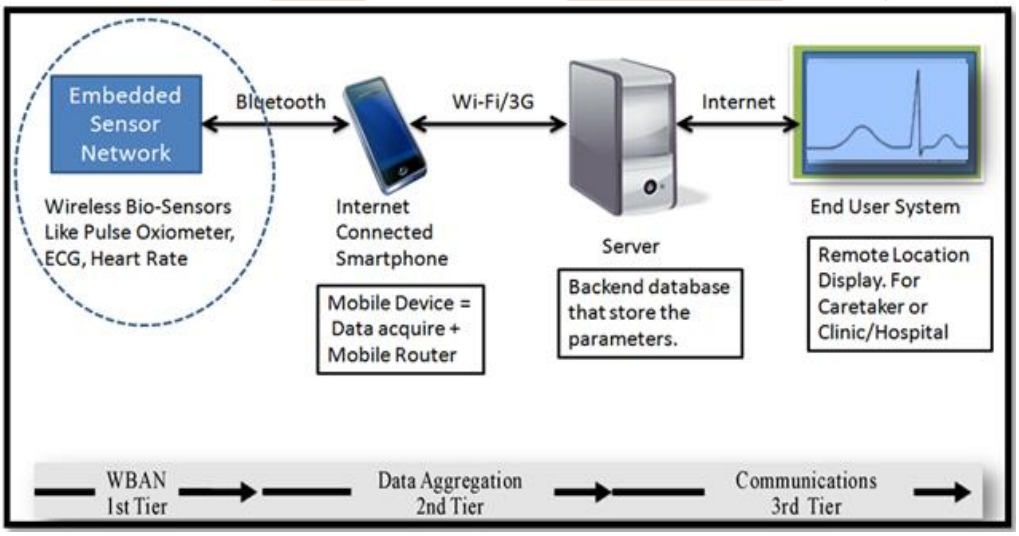

Fig.1. Block Diagram of Architecture Wireless Body Area Network.

Protocols that used in WBAN are IEEE 802.15.1 Bluetooth, IEEE 802.15.4 ZigBee and alliance of it Xbee, ANT propriety technology. Here Bluetooth protocol is used to implement desired system where Bluetooth is working on master-slave topology (1 master-7 slaves), 2.4 GHz of ISM band, GFSK and FHSS modulation used, also communicate based on Time Division Multiple Access (TDMA), 10-100 meter of distance range.

Android mobile device works as mobile gateway to acquire the data which senses by body sensors and forwards to the clinical web. Clinical Web gets forwarded data, store and display. For Communication either cellular data network or IEEE 802.11 standard is used. Major implementation and design is to develop embedded device that sense and sends data.

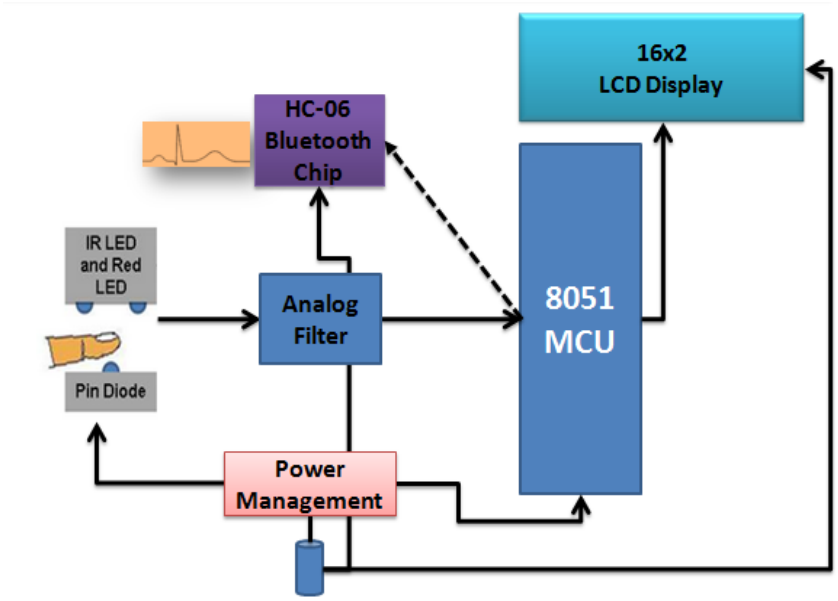

Fig.2. Block diagram of Bluetooth based heart monitoring device.

A. Heartbeat Sensor

Heart beat sensor works on principle of light modulation by blood flow through finger at each pulse. Operated on +5V DC regulated. The sensor is consisting of bright Red LED (660nm) and light photo sensor. The LED needs to be super bright as the maximum light must pass spread in finger and detected by detector. Now, when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reached the detector. With each heart pulse the detector signal varies. This variation is converted to electrical pulse. This signal is amplified and triggered through an amplifier which outputs +5V logic level signal.

B. Microcontroller And Other System Component

In proposed system AT89S52 atmel microcontroller is used. This microcontroller architecture is based on most popular and basic 8051 microcontroller. Analog filtering is used to amplifies and smooth the actual output of the sensed data. Get the digital output from the heart beat sensor and computer the count per heart beat. Each heartbeat reading taken as 10ms delay that avoids noise and error in sensing data. Efficient power management distributes different voltage of power to microcontroller, heart beat sensor as well LCD (16x2) display and HC-06 (Bluetooth module) as shown in fig. 2.

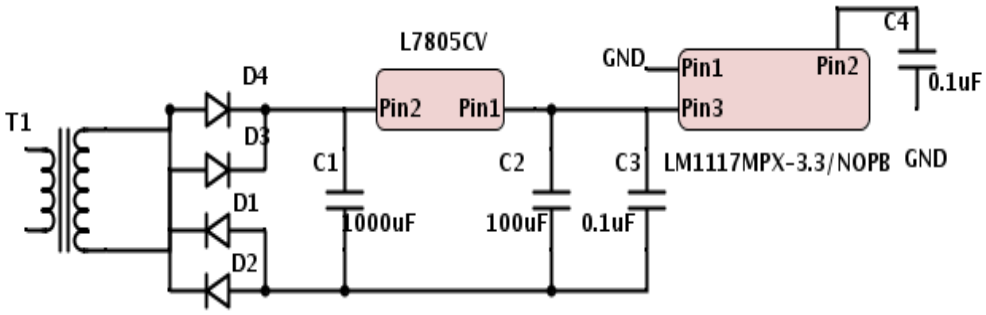

Fig.3. Circuit of Power management in heat beat monitoring device.

L7805cv integrated circuit is used to regulate the voltage and convert 12V to 5V. Required capacitors are used to avoid the fluctuation in voltages. Efficient microcontroller program count the heart beat and store into the array. Averaging performed on heartbeats count and display the actual heart beat of human body on 16x2 LCD display. Same heart beat count sends to the Bluetooth module in specific data format by microcontroller. Bluetooth module receives and sends to the android gateway.

C. Data Packet Format

Heart Beat data to be calculated by the microcontroller and display on the LCD. Same heart beat count to be transmitted to Bluetooth module for forward to android based gateway device. Serial data is formed into a specific frame or byte stream. That is transmitted on each change event.

Transmitted frame is form of 7 Byte. Starting bit is “aa” that is called preamble bit then 3 bits of the heart rate reading. At 4th position there is a “;” that differentiate the readings then new line and carriage return which points to the starting bit of next frame. For example consider at each heart beat reading changes. So this formulated frame is such like below.

For Example: 095;
Serial date (Hex): aa 30 39 35 3b 0a 0d

Starting	Hear Beat Reading			Semicolon (;)	Line feed (/n)	Carriage Return
aa	1st Digit	2nd Digit	3rd Digit	3b	0a	0d

Fig.4. Data packet format

D. Android Mobile Gateway Implementation

Android is more popular open source mobile technology. Remote based m-health has new option to develop android based gateway which is easy to interface and easy to configure with existing and new technology. Hex data packet sends by Bluetooth module received by android gateway. Android gateway processes data and display it in appropriate decimal format. Accelerometer sensor has three x, y and z values of motion also gathered by android device itself. No need of extra external hardware required for the accelerometer values. Accelerometer sensor values shows motion of patient. A different java activity has been coded in the core of android application. Main activity calls other sub activities to pair with Bluetooth device and monitor physiological reading of human body parameters.

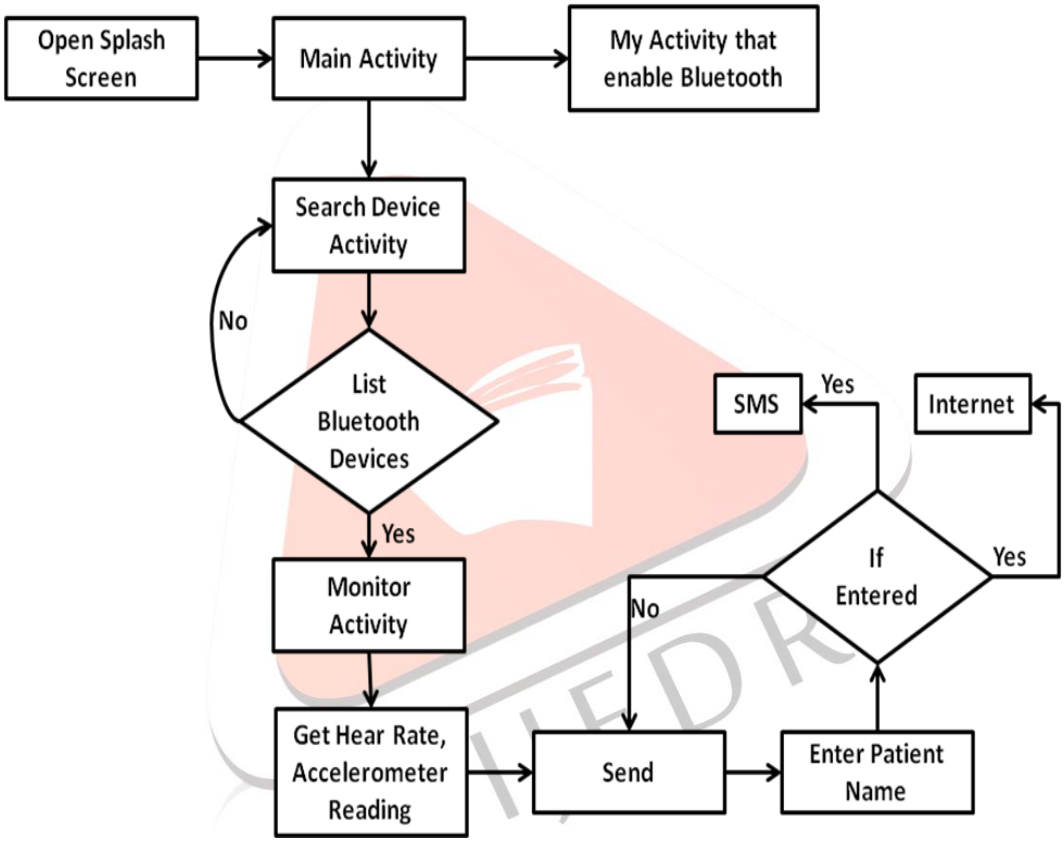

Fig.5. Dashboard java flowchart

Heart Beat readings further forwarded either by sms or using internet connectivity to clinical web. Clinical web assistant developed in php opensource technology. Which gets readings and sends respective acknowledgement to the android mobile gateway. Patient Name, Heart Beat in BPM, Accererometer sensor values (X,Y,Z) to framed into on data packet. Using cellular data network 2G/3G or use of wi-fi this entire data packet sends to clinical web assistant which display the entire data in perodic refresh time with date and time attributes.

IV. Results And Discussion

A Bluetooth based mobile heart beat monitoring system prototype was designed and implemented including hardware and software associated with three main components: smart Bluetooth based heartbeat monitoring device, efficient and smart android based mobile gateway web health TeleCare information system.

Regarding android based mobile gateway test, performed in Android 2.2 and above all versions. Easy to communicate with Bluetooth module and received the heat beat readings also shows x, y, z accelerometer sensor value form device itself. Figure.6 shows decimal heart beat values as well acc. Motion sensor values, hex code of the reading.

Fig.6. Android mobile gateway

Performance testing of android mobile gateway with working of Bluetooth, 2G/3G or Wi-Fi also represent with graphs in figure.7. Graph shows the CPU load, Bluetooth state, memory usage of the android gateway while taking reading from Bluetooth based heart monitoring device.

Data packet sends by the gateway to the clinical web server over the internet connectivity can easily shown in graph. Transmitted data packets are 5 and receiving data packet is 2. Receiving data packet is fixed of 431 Byte while transmitted data packet is around 570 Byte. A comparison of graphs shows request and response between Cellular Data Network and Wi-Fi. It may vary with the speed of data plans. Given comparison is performed under the 2G cellular data plan of Tata Docomo and 250kbps wi-fi data plan. Graphical Represents shows the graph of change in Bluetooth state, CPU Load, CPU Frequency, Memory Usage

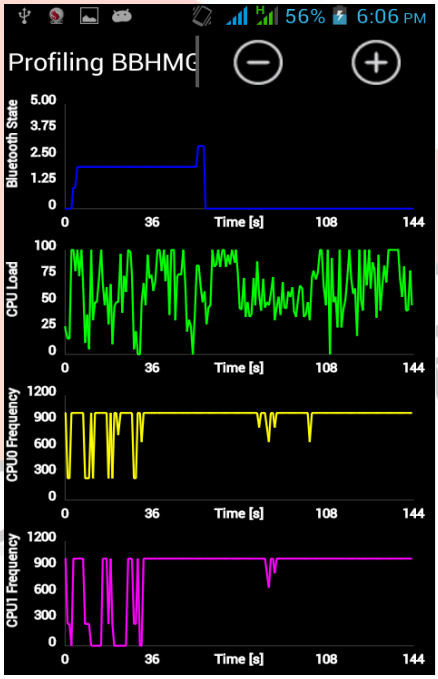

Fig.7. Performance graph of android based mobile gateway

Fig.8. Comparison of Cellular data Plan Vs Wi-Fi Connectivity

Clearly shows the difference in speed of data transmission over two different data networks. In Wi-Fi easily data packet sent over 1.2 KB/s of speed whereas in cellular 2G data it sends data with 1000B/s of speed. It may vary with respect of data packet speed. Based on these performance test results shows efficient working of m-healthcare systems.

V. Conclusion

As the elderly and chronic disease patients are increased they required more medical support from their care takers. Other side care takers or hospital need to provide quality of medical service to their patients. In such a situation any time and any where measureable bio medical parameter of human body make helpful to both patient and care takers. A Bluetooth based continuous heart monitoring device measures the heart rate of patient and transmits to the smart android based mobile gateway device that forward the measurement to care takers directly. No need to go clinical site or hospital. Remotely the actual reading of the patient can get. Here is the one of the scenario where heart beat takes as bio medical parameter, but it's possible to add more parameters and provide it. Wireless communication between devices opens new opportunity for m-healthcare solution in medical technology.

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