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An End-to-End Point of Cardiovascular Body Sensor Network with Cloud Service

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Abstract*: *India is the world capital of cardiovascular diseases and there is an immense shortage of doctors to serve the patients. This work focuses on cardiovascular sensor data collection and processing. Unlike other wireless body sensor network where the parameters are discrete, often cardiovascular data analysis needs continuous data at a high sampling rate. Such wireless signal gathering over a continuous wireless channel hasn't been proposed so far due to critical consequences of noise in that signal during transmission. Furthermore, existing many techniques proposes a small data collection in a local node and then dissipating them to cloud. But, continuous wireless sensor signal data transmission and simultaneous processing hasn't been successfully performed. This work addresses the aforementioned issue and delivers an end-to-end sensor network solution to acquire continuous cardiac signal, transmission to a local processing node and mitigating the data to cloud in real time and also implemented simple heart rate monitoring algorithm of the cloud to visualize continuous heart rate of a patient with this sensor node.

***Index Terms*: *Cardiovascular Disease (CVD), Electrocardiogram (ECG), Biomedical Single Processing (BSP), Ballistocardiograpy (BCG), Artificial Neural Network (ANN), Artificial Intelligence (AI), Wireless Sensor Network (WSN)*.**

I. INTRODUCTION

A wireless sensor network is a network where several sensor nodes communicate to mitigate acquired sensor data to a central or distributed storage for data analytics. A body sensor network is essentially multiple isolated or physically connected sensor nodes that collects multiple health vitals like temperature, respiratory rate, skin resistance, ECG, pulse and other signals and transmits them wirelessly to a sink node.

A WSN is a network of fully functional sensor nodes. A sensor is an electronic device capable of converting analogue data or other parameters into digital form. This digitally sampled and quantized data are stored in a local storage of the sensor node

The main function of the sensor network is to dissipate the data wirelessly to a special node which is called a sink node. A sensor node is often a small electronic device that is operated by battery and has a limited life, data processing and transmission bandwidth. Hence, these nodes cannot be able to process complex data or to apply complex decision processing algorithms. Such decision must be taken at a computing node with much higher energy and power.

These nodes are often called an edge device. An edge device is one that acts as an interface between data and cloud. Once the data is gathered by the sink/edge node, it is processed locally. Redundant data is filtered and then sent to a cluster node. A cluster node is a computationally superior node or a server which has the capability of gathering and storing large volume of data coming from various sink nodes.

The following figure 1 depicts the high level architecture of the proposed work. Internet of Things (IoT) service is most vital medium which connects the IoT devices and end users. Sensor devices collect the data and stored in the cloud database. By fetching these stored data from the database, users can analyze the data and send an analyzed report back to the end users through IoT services.

II. RELATED WORK

[1] A biomedical signal processor (BSP) with hybrid functional core is proposed. This proposed BSP is designed based on hybrid cores of (i) biomedical core (ii) 32-bit RISC core (iii) crypto core. Different methods like discrete wavelet transform and adaptive threshold are used for QRS detection.

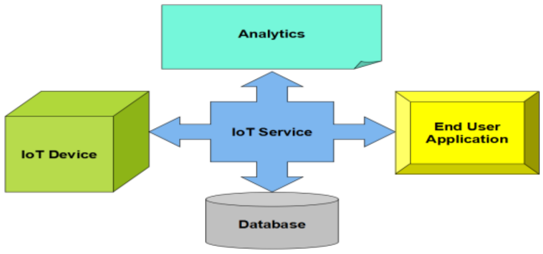

Fig 1: High level architecture

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An adaptive matched filtering algorithm [2] Based upon an Artificial Neural Network (ANN) for QRS detection has proposed. ANN adaptive whitening filter is used to model the lower frequencies of the ECG which are inherently nonlinear and non-stationary. In [3] various smart devices and services to prevent diseases and to improve health based on sensory data to realize the condition of health. Lifestyle and vital signals plays a important role for realizing them. In this approach health related issues are discussed to consider the establishment of new systems approach of healthcare.

[4] Proposes a method of detecting heart rate finding the periodicity of Doppler frequencies that depends on heartbeat. This approach used the autocorrelations of wavelet coefficients in a frequency range and selects the most periodic frequency component by evaluating the peak ratio and heartbeat interval is extracted from it. The [5] presents the design of a novel wireless sensor network structure to monitor patients with chronic diseases in their own homes through a remote monitoring system of physiological signals. The scheme [6], discussed how methods are used for pitch tracking in speech processing, can be applied to the problem of beat-to-beat heart rate estimation from BCGs. The proposed methods are evaluated with respect to RR-intervals obtained from a reference ECG. The [7] scheme involves analysis of an enhanced ECG compression and de-compression method. A simple ECG peak detection method based on characteristics of ECG signal is proposed. Authors have used Huffman encoding algorithm for subset of all possible Discrete Cosine Transform values to achieve better compression. Author [8] has proposed a new R-peak detection algorithm for single lead mobile ECG recordings. Proposed algorithm is simple to implement, computationally efficient, and does not require any signal pre-processing. In [9] an on chip real time automated ECG frame identification methodology for obtaining the complete ECG frames in an automated fashion by identifying the start and end points of ECG frames are proposed. The [10] scheme uses a physiology based source separation (PBSS) technique. The main limitation of the existing PBSS is the susceptibility to artifacts in the estimation of the electrical axis.

III. METHODOLOGY

The current standards of medical diagnosis of the cardiovascular diseases involve ECG or alike devices with the clinicians. The clinicians need to acquire the data, print the signal trace and then look for anomalies. Some of the current devices also adapt the method of AI based diagnosis where the ECG data acquisition is stored locally in an edge device like mobile. Then the data is mitigated to cloud and a machine learning based approach is adapted to analyze the data and generate meaningful reports. However, most of these devices are extremely costly and mostly are 12-lead which are complex in terms of usage as well as are time consuming.

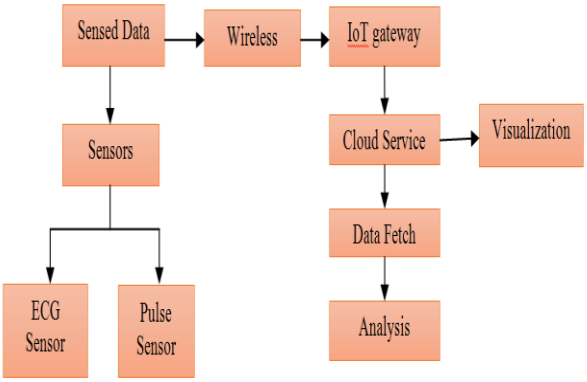

Fig 2: Block diagram of the proposed work

Actually, few of the current research work or commercial grade clinical devices provide accurate cardio vascular analysis using a low cost device. Not only the current devices are cost extensive, they are for particular purpose. i.e. most of the devices acquire single domain signal. Therefore, vascular analysis is missing in most of the current devices. By using multiple sensors, better snapshot of the organ system can be obtained which can then be used to take better clinical decisions.

In the proposed architecture, the clustering node is the internet gateway that mitigates sensor data to the cloud. If a sensor network has multiple isolated wireless nodes then a routing function is used to send data from different sensor nodes to the respective sink node. The routing protocol is adapted to maximize the lifetime of the sensor node. The lifetime of a sensor network is defined as the total time from the beginning of the network till the time when the first sensor is drained out of the battery life. The sensor network adapts different routing protocols based on its data mitigation fundamentals.The figure 2 describes the block diagram of the proposed system.

A. Proposed System

The sensor network can be either event driven or time synchronous. A time synchronous system is one where the objective function of the network is that the sensors send their data to a particular sink node over and over using a clock which is aligned to all the nodes of the network; An event driven sensor network is one where the sensor nodes send the data only when a particular event is generated like a fire alarm. This type of sensor network adapts which is called a query based sensor network.

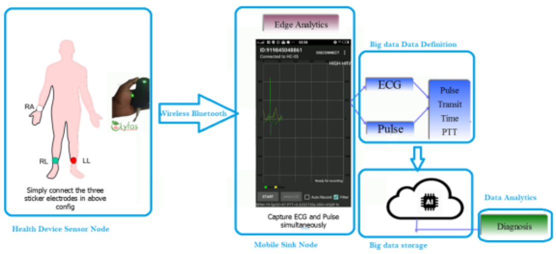

Fig 3: Overview of an architecture

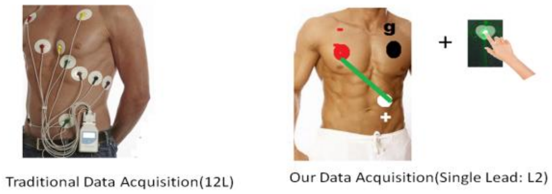

Fig 4: Traditional V/s proposed data acquisition method

Here, the sensors start capturing and sending data based on a particular user query. The proposed research work inculcates query driven sensor network where the connection between a sensor and a sink node is established on demand which is initiated by a data request query generated by the sink node or the mobile app.

The adapted routing protocol used in the proposed work is direct diffusion as the numbers of sensors are limited. The objective of the sensor network is to maximize the data quality as the sensor battery can be easily recharged.The proposed system is a healthcare device that has two sensors: Electrocardiogram sensor and the pulse sensor. These sensors act like source nodes. When the device is connected to the patient, a Micro controller unit extracts continuous data of 120 minutes from the sensors and sends to the local edge mobile device which is called a sink node using Bluetooth technology. The sink node then mitigates the data to the cloud using IP gateway. Once the data acquisition and transmission sessions are completed, an analytic engine in the cloud is getting connected to perform data analysis and to acknowledge the edge devices. Figure 3 demonstrates the overview of the proposed architecture.

The figure 4 illustrates the comparison between data acquisition technique in present and proposed system. In existing system 12 Lead ECG method is used to capture ECG signals from the patient. It is too complex to place all 12 electrodes on the body surface of the patient, where as in proposed research work only 3 Lead ECG method is used to acquire the ECG signals from the patient. Thus, it is very easy to mount three electrodes on patient body as shown in fig 4.

B. Sensor Node Development

The proposed sensor node has two main sensors that is AD3282 and Pulse sensor. AD3282 is a single channel ECG sensor and maximum heart rate sensor which is a pulse volume signal acquisition module based on green light LED and finger capillary blood reflection. These two sensors are connected to Micro controller STM32 which acts as the processing entity in the sensor node. The sensor node is powered by a Lithium Ion battery of 3.7 volts and is rechargeable. The booster circuit is used to charge the battery and the sensor is connected to a Bluetooth HC-05 device which is used for sensor node to sink node data transmission. The figure 5 shows the circuit diagram of the sensor node.

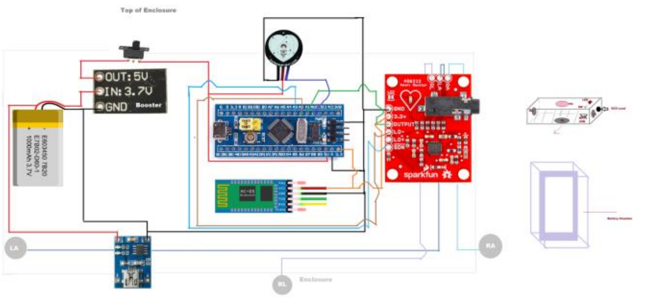

Fig 5: Circuit diagram of sensor node

C. Sink Node Development

The sink node is an edge device which is an Android mobile application. The sink node is an android app, when initiated gets paired up with the source health device node. The edge device and software then simultaneously acquire ECG and pulse data coming from the sensor node using Bluetooth serial communication. The data is stored in a file. Once the recording is completed, this data file is stored in a cloud space using storage API and invokes an analytics engines as shown in above figure 6.

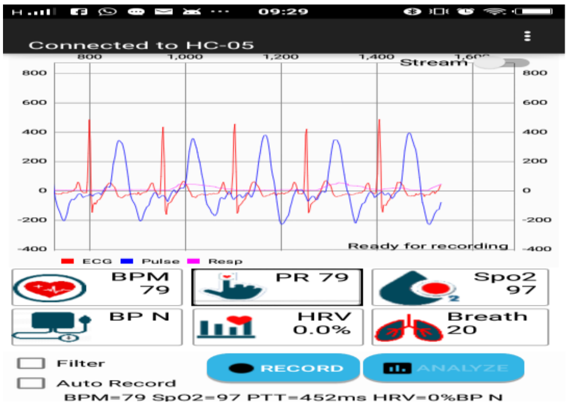

Fig 6: Mobile sink node in action

Fig 7: Hardware health sensor node

This above figure 7 shows the hardware device which is outcome of the proposed work. The figure 8 demonstrates that captured ECG signals, analysis of the data parameters with their normal range. The proposed system analyzes the data acquired in mobile for 10-30 seconds. The analysis results gives the result of different parameters like length of average ST segment is 65 ms, standard deviation of RR interval is 11.41, QRS dispersion in is 51.76 ms and so on.

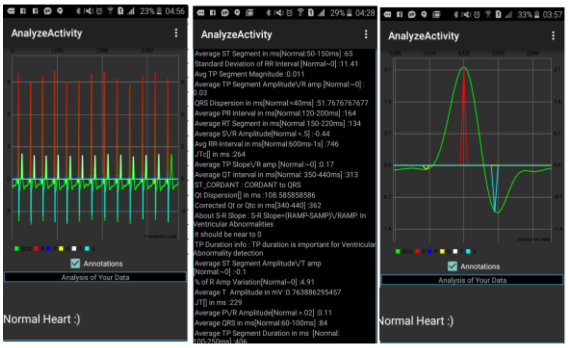

Figure 8: Analysis of result in the mobile edge sink node

The outcome of the overall research work is an end-to-end system that includes a fully functional sensor healthcare device node and an edge processing engine running on an android phone that captures the data from the sensor node and then mitigates the data to a cloud storage system. Then, the system should call the cloud based analysis as an API service and render the result in the mobile. The system should be able to detect and diagnose specific diseases. The figure 8 determines an analysis of the result in the android mobile phone.

IV. CONCLUSION

The work focuses on developing an end-to-end point of healthcare solution for diagnosis and monitoring of cardiovascular diseases by combining the principles of wireless sensor network and big data analytics. the hardware is developed from the basic components and created a cardiovascular health device that will capture both ECG and pulse signal, there by satisfying the idea of multiple sensor data node. in addition to this, a framework has built to capture the sensor data wirelessly by a wireless sink node over blue tooth connectivity. an ip gateway deployed at the sink node is used to mitigate the captured multi parameter sensor data into a cloud storage provider. data visualization and processing techniques can be applied at the cloud for efficient data processing. this system can be further improved by incorporating several other sensors such as sound sensor for stethoscope and respiratory sensor for breathing. the system can be developed into fully functionally point of healthcare solution.

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