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Cloud-Based Wireless Body Area Network for Healthcare Monitoring System

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Abstract—*Wireless Body Area Network is a collection of wireless sensors attached on or implanted in the body that are used to monitor physiological signs of the body. WBAN does not restrict patient to stay at the hospital for health monitoring thereby increasing physical mobility and increased efficiency of healthcare system. This paper presents the behavior of the WBAN system and cloud computing concept. Also the need of integration of cloud computing and WBAN is explained. The integration leads to the introduction of new platform for scalable and on demand processing of huge amount of data collected from WBAN.*

1. INTRODUCTION

The aging population and growing costs of healthcare [1] in many developed countries leads to the introduction of technology driven enhancements to the current healthcare practices. WBAN is one such technology that has the potential to improve healthcare monitoring and related medical procedures. With the use of WBAN the patient experiences a greater physical mobility instead of staying at the hospital. This further enhanced the personal health care and the cost of the healthcare system is reduced. This system is better than traditional wired based patient health monitoring system because WBAN provides better rehabilitation. As in case of wired system, wires are used to connect multiple sensors which restrict patient's mobility. In contrast WBAN use small low power sensor nodes with wireless capability.

Wireless body Area Network [2] consists of number of small, lightweight and intelligent sensor nodes attached on or implanted in the body with wireless capability. These nodes monitor the patient's vital signs such as Electrocardiogram (ECG), blood pressure etc. This data from all WBANs may be sent to a centralized repository for permanent records. Medical practitioners can remotely access this data to access the state of patient's health. Also the patient can be alerted with the help of SMS, alarm or reminder messages. A WBAN can be used to offer assistance to the disabled. For example, a paraplegic can be equipped with sensors determining the position of legs or with sensors attached on the nerves. WBAN can be used in different applications like public safety by firefighters, policemen etc.

WBANs are the extension of WSNs application, but there are obvious differences between WBANs and WSNs [3]. Compared with traditional wireless networks, WBANs have some unique features.

(1) Node Deployment and Density:

WBAN nodes are deployed on the human body or hiding under the clothes. WSNs are often deployed where the user is not accessible. WBANs do not solve the lost node problem by adding redundant nodes that are different from common WSNs design. Next, these implanted sensor nodes are difficult to replace and charge. The replacement of wearable sensor nodes is also invasive to the human body and introduces some human body discomfort.

(2) Limited Energy:

WSNs are mainly used for transaction monitoring, and the occurrence of these transactions interval is irregular. By contrast, WBANs are used to record the body's physiological activities; they usually occur periodically, so the data flows show relatively stable rate. Each node of WBANs will carry out different target parameters' acquisition and send them in different frequency and data transmission rate, so it requires higher energy consumption. Next, signal transmission attenuation is large because of the specificity of the body tissue structure and the shadow effect. This can cause a large path loss of a transmitted signal. So, WBANs communication requires more energy than other networks under the same size.

(3) Delay:

The delay may be related to the stability and energy consumption. It is difficult to replace batteries because the environmental influences after the nodes are deployed in WBANs. And the power control is more difficult due to the energy consumption requirements of nodes; the communication coverage of WBANs nodes is much shorter than mobile cellular phones. So increasing the battery lifespan is necessary, even at high delay.

(4) Mobility and Security

WSN nodes are often thought of as stationary; the node of WBANs will move with the user activity. The wireless signal spreads in the body or on the body surface; it needs to consider the safety, reliability, and long term operational ability of human body.

Types of devices used in WBAN [2]

1) Sensor node

A device that responds to and gathers data on physical stimuli, processes the data if necessary and reports this information wirelessly. It consists of several components: sensor hardware, power unit, processor, memory and transmitter or transceiver.

2) Actuator node

A device that acts according to data received from the sensors or through interaction with the user. The components of an actuator are similar to the sensors: actuator hardware (e.g. hardware for medicine administration, including a reservoir to hold the medicine), power unit, processor, memory and receiver or transceiver.

3) Personal device (PD)

A device that gathers all the information acquired by the sensors and actuators and informs the user (i.e. the patient, a nurse, a GP, etc.) via an external gateway, an actuator or a display/LEDS on the device. The components are a power unit, processor, memory and transceiver. This device is also called a Body Control Unit (BCU), body gateway or a sink. In some implementations, a Personal Digital Assistant (PDA) or smart phone is used.

Many different types of sensors and actuators are used in a WBAN. The main use of all these devices is to be found in the area of health applications. In the following, the term nodes refer to both the sensor as actuator nodes.

The number of nodes in a WBAN is limited by nature of the network. It is expected that the number of nodes will be in the range of 20–50.

1.1 System Behavior / Activities

According to the type of illness [4], the patient wears the specific physiological sensors to measure the vital-sign parameters. The captured data is collected by all sensors and transmitted to the data aggregator. This data is then transmitted to the gateway by the short-range wireless communication module in the device in order to continuously monitor and record the patient's condition.

The end to end transmission path of data stream is shown in Fig. 1.

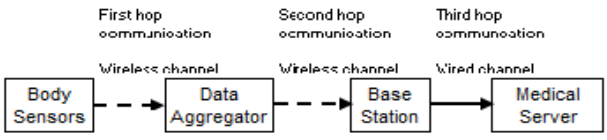

Fig. 1: Transmission path of data stream

The transmission consists of three hops of communication:

1) The first hop communications, which occur from body sensor to the data aggregator via wireless channels.

2) The second hop communications, which occur from the data aggregator to base station via wireless channels.

3) The third hop communications, which occur from base station to the medical server via wired channels.

Thus this network always gets connected with the gateway and transmits the vital-sign parameters to the gateway by means of multi-hop configuration. The gateway is primarily responsible for collecting and recording the patient's vital-sign data. The server which is located in the hospital, stores the data from every gateway into database. Type of sensor used in WBAN depends on user application like

An ECG sensor used to monitor heart activity
An EMG sensor used to monitor muscle activity
A blood glucose level sensor
A body temperature sensor
A SpO2 sensor for monitoring body Oxygen Level
A pulse rate sensor etc.

The purpose of the communication path is to transmit collected data from each sensor node to the PC.

2. CLOUD COMPUTING

Cloud computing [5] is a distributed computing paradigm that focuses on providing a wide range of users with distributed access to scalable, virtualized hardware and/or software infrastructure over the internet. It implies a service oriented architecture, reduced information technology overhead for the end-user, greater flexibility, reduced total cost of ownership, on demand services and many other things. In cloud computing, large set of systems is connected to public or private networks, to provide dynamically scalable infrastructure for application, data and file storage. It refers to the delivery of computing resources over the Internet. Instead of keeping data on your own hard drive or updating applications for your needs, you use a service over the Internet, at another location, to store your information or use its applications.

Cloud computing offers the following benefits:

1) Reduced Cost

There are a number of reasons to attribute Cloud technology with lower costs. The billing model is pay as per usage; the infrastructure is not purchased thus lowering maintenance. Initial expense and recurring expenses are much lower than traditional computing.

2) Increased Storage

With the massive Infrastructure that is offered by Cloud providers today, storage & maintenance of large volumes of data is a reality. Sudden workload spikes are also managed

effectively & efficiently, since the cloud can scale dynamically.

3) Flexibility

This is an extremely important characteristic. With enterprises having to adapt, even more rapidly, to changing business conditions, speed to deliver is critical. Cloud computing stresses on getting applications to market very quickly, by using the most appropriate building blocks necessary for deployment.

In Fig. 2, Cloud Computing provides three service models [6] and these three models club to form cloud computing architecture. The services are:

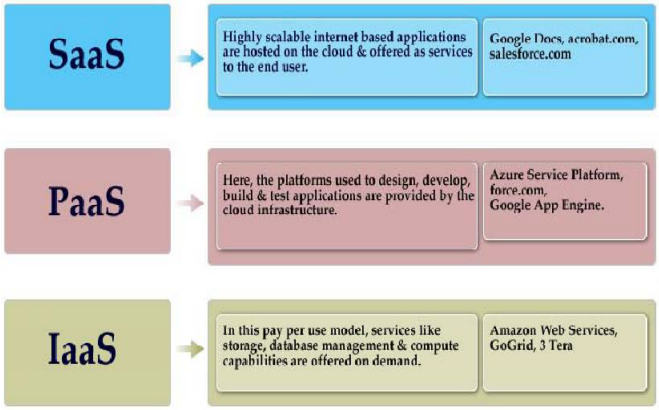

Fig. 2: Cloud models

Infrastructure as a Service (IaaS): The infrastructure layer builds on the virtualization layer by offering the virtual machines as a service to users. Instead of purchasing servers or even hosted services, IaaS customers can create remove virtual machines and network them together at will.

Platform as a Service (PaaS): The platform layer rests on the infrastructure layer's virtual machines. At this layer customers do not manage their virtual machines; they merely create applications within an existing API or programming language. There is no need to manage an operating system.

Software as a Service (SaaS): Services at the software level consist of complete applications that do not require development. Such applications can be email, customer relationship management, and other office productivity applications. Enterprise services can be billed monthly or by usage, while software as service offered directly to consumers, such as email, is often provided for free.

3. CLOUD AND WIRELESS BODY AREA NETWORKS

Cloud computing is used in integration with WBAN [7] as the huge amount of data collected by WBAN requires scalable, on-demand, powerful, and secure storage and processing infrastructure. This integration of these two communication technologies leads to the introduction of hybrid platform that must be capable to process the huge amount of data collected from WBAN sensor nodes. This allows user to transmit the data to the cloud with low power and low delay. The cloud computing links different sensor nodes attached on or implanted in the body with the high performance supercomputers. The main goal of this integration is to develop a large scale WBAN system in the presence of cloud based data collection model.

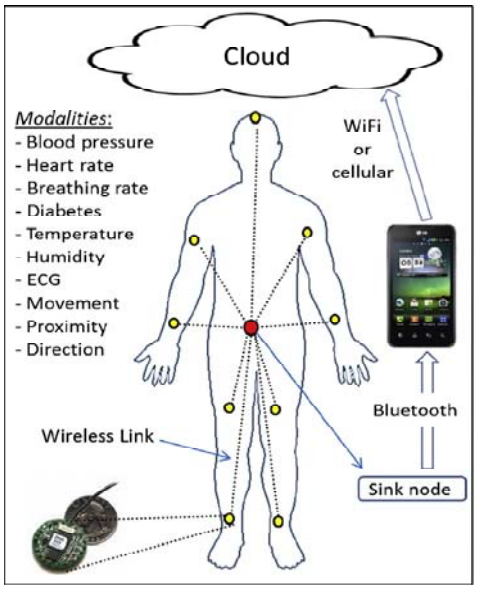

Fig. 3: Cloud and Wireless Body Area Network

In Fig. 3, the healthcare system monitors the medical condition of the patient and updates the patient's health status in the cloud by means of smart phone or wifi connection [8]. Any abnormalities that needed immediate treatment then patient can be asked to visit the healthcare facility. If not needed then data can be logged into the cloud and registered by patient's ID for future reference.

4. INTEGRATED ARCHITECTURE

Fig. 4 describes the integrated architecture of Cloud computing and WBAN.

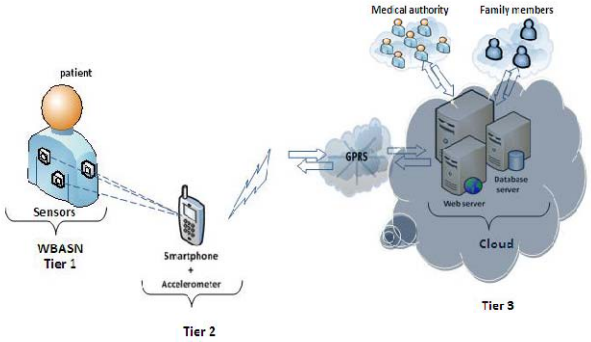

Fig. 4: Integrated Architecture

This architecture is composed of three tiers:

First Tier (Wireless Body Area Network):

This tier is considered as the lowest tier of the architecture. WBAN include number of sensors like ECG, EEG, motion sensor etc. These sensor nodes monitor different physiological signals like ECG monitor heart activity. These nodes perform sensing, sampling and signal processing. All the body sensor nodes are in close vicinity to centralize personal server.

Second Tier (Personal Server):

Tier 2 comprises of personal server which provides transparent interface to the wireless sensor nodes, user, and the medical server. This interface includes network management as well as configuration. The personal server is capable of determining patient's health status and also provides feedback by using user friendly and graphical interface. Depending on the network, PS runs on smart phone or PDA.

If the communication channel between personal server and cloud is available then the PS will establish a link to the cloud and sends the reports regarding patient's health status. If a link is not available to the cloud then personal server stores the data locally and transmits the data when the links become available.

Third Tier (Cloud Medical Server)

This tier encompasses a cloud medical server accessed via internet. The collected monitored data are processed in the cloud and then selectively transmitted to the users. This server keeps records of users and provides various services to the users and medical practitioners. Doctors can access the data with the help of internet and examines the data to ensure that the patients are within health metrics and whether they are responding to the treatment. A server may check the uploaded data for any abnormality and create an alarm in case of any potential medical condition.

5. RELATED WORK

From our literature survey we have observed that the integration of WBAN and cloud computing provides scalable, on demand and secure architecture for storing huge amount of data collected by the sensors. With the help of cloud computing, WBAN user will be able o transmit the data with low power with the use of wifi.

In [8], authors present cloudlet-based efficient data collection system in WBAN. Their major goal is to have large scale of monitored data of WBANs to be available at the end user or the service provider in reliable manner. The objective was to decrease the power and delay of the collected data by dynamically choosing data communication technology in the monitored area.

The overview of current and past projects is given in [2]. Also the open research issues and challenges are pointed out in this paper. Authors focus on some applications in patient monitoring. This work presents MAC protocols, routing protocols, Quality of Service and security.

In [5], authors discusses the concept of "cloud" computing, some of the issues it tries to address, related research topics, and a "cloud" implementation available today. Cloud implies a service-oriented architecture, reduced information technology overhead for the end-user, great flexibility, reduced total cost of ownership, on-demand services and many other things.

A prototype of cloud mobile health monitoring system is proposed in [9]. The system uses WBASN and Smartphone application that uses cloud computing, location data and a neural network to determine the state of patients. The system provides the architecture for collecting, gathering and analyzing data from a number of biosensors using WBASN, Personal server and cloud medical server.

In [10], authors discuss the existing architecture of WBAN. Also concept of virtual doctor server (VDS) is proposed to support various patient health care services. The aim is to investigate the role of WBAN in improving quality of life. The challenges and open research area is also discussed in this paper.

6. CONCLUSION

This paper deals with the need of scalable, on-demand and secure processing of huge amount of data collected from the sensors of WBAN system. For this, integration of cloud computing is done with the WBAN as cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This integration of two communication technologies leads to low power and low delay of the collected data.

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