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Health monitoring system in Wireless sensor networks

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Abstract: Wireless Sensor Networks (WSN) have arrived and attracted in today's business, education, social and healthcare field. There are lots of applications developing in this fields using Wireless Sensor Network. Due to the increasing pressure in healthcare industry specially health monitoring application; wireless sensor network plays a vital role. Using six different wireless sensors in health monitoring system; patient's data can be captured remotely. There is no need for doctor's visit to a patient periodically. This paper discusses about the basic wireless technologies of medical applications like WBAN, WIMAX, and WLAN etc. The paradigm used for mobile sensor networks in health monitoring system as well as existing system architecture are also discussed in this paper. This paper also identifies about the innovative technology of medical applications using wireless networks. The advantages as well as technological challenges for using the wireless medical devices are also focused in this review paper. The proposed future development using wireless network is also discussed in this paper.

Keywords: WBAN, WIMA, WLAN, WSN, WWBAN

I. INTRODUCTION

A WSN (Wireless sensor network) contains small, portable and lightweight multiple sensor nodes. The sensor nodes are detection stations that comprised with a microcomputer, transducer, transceiver and power source. In case of health monitoring system, the electrical signals based on the physical effects of human body are generated by transducer, processed and stored by microcomputer and commands received and transmitted by transceiver. Battery is the power source for each sensor node.

The wireless sensor network is applied for habitat monitoring [7], traffic monitoring and guidance, health monitoring and guidance, plant monitoring [8], environment monitoring and infrastructural monitoring. The wireless sensor network has great role in healthcare applications such as medical data access, medical monitoring and communications with doctors through SMS or GPRS [1][2]. The emergency condition of patients can be determined by continuous health monitoring with clothing-embedded transducers [3] or body sensor networks [4]. These system is able to monitor the patient's physiological signals without hampering their normal life and tends to increase their life quality [5][6]. In current bed side equipments, the limitation is found like sensors should be placed beside monitors as well as patient is able to move only certain distance. Naturally, Commercial 3G networks or WLAN are used for current health monitoring system.

Wearable health monitoring system is limited by the distance to find the vital signs of patient for maintaining health status. If patient requires continuous long-term monitoring as part of the diagnostic procedure or surgical procedure then wireless monitoring system is must. As long-term monitoring is helpful to capture the circadian variations of patients (by physiological signals) that tends to recover indication for cardiac patients. [2] The different rehabilitation like surgery after hip or knee, stroke or brain trauma can be done by long-term monitoring.

The WSN is able to monitor the various health parameters for detecting the emergency condition by specialists. The varieties of sensors like BP, pulse rate, body temperature, ECG etc. are attached with portable devices of WSN. These cost-effective sensors have radio communication capabilities that are able to capture real time health data from patient's body and transmitted these to the specialist's devices (cell phone or PDA). The following figure shows as,-

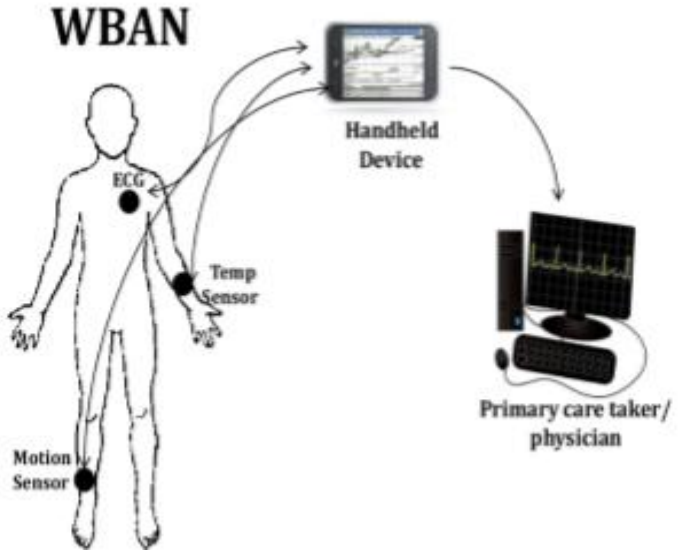

Fig 1: Wireless Body Area Network

The above fig. tells about Body Area Network which is a type of wireless sensor network. The main advantage of WSN system in healthcare monitoring is to easily accessible of patient's updated data from anywhere and anytime by specialists as well as specialists can take immediate action in emergency situation with lost cost [10].

The WWBAN (Wearable Wireless Body/Personal Area Network) can monitor vital signs by physiological sensors and a location sensor [9] that can allow long-term ambulatory health monitoring with feedback in real-time or near real-time update of the patient's health status.

This following paper is organized into different sections. The third section discusses about the background analysis of Medical sensing and wireless sensors platform. The fourth section tells about basic wireless technologies for medical application, fifth section discusses about possible paradigms for Body Area network and sixth section focuses on the detailed system architecture for WSN. Various technological challenges for WSN as well as future development in health monitoring application are also discussed in the later sections.

II. LITERATURE REVIEW

There is a background about using sensors in healthcare application. The different sensors embedded with variety of medical equipments in home, clinics and hospitals to monitor the physical and physiological health status of patients. These sensors are blood pressure monitors, thermometers, glucose monitors, EEG, ECG, EKG, PPG and imaging sensors. The different physiological sensors like pacemakers, insulin pumps are able to detect electrical, thermal, chemical signals. The different dimensions of medical sensing technologies are discussed as follows,-

1. Sensing Modality: The previous technologies are updated by advanced technology like MEMS, imaging and nanofluidic lab-on-chip that leaded to new forms of biological, chemical and genomic sensing. These new inexpensive technologies resolved public health crisis by early detection and treatment from infectious disease.[11]

2. Size and cost: Previous medical sensors were costly and complex and were difficult to use outside the clinics. But, recent advancement of microelectronics; these sensors is portable as well as cost-effective. Firstly, the portable medical sensors arrived for measuring BP and blood glucose without doctor's intervention that are necessary for continuous monitoring of hypertension and diabetic patient.[12] The ambulatory medical sensor is invented next for easily carrying with the patient. This sensor is able to measure physiological parameters like wearable heart rate, Holter monitors and other physiological parameters of the patients to target fitness enthusiasts and health consciousness. Next, embedded medical sensors developed for assistive devices of geriatric [13]. Again, the implantable medical sensor is invented to measure internal health and physiological status. This sensor is very much useful for monitoring intraocular pressure in glaucoma patients [14].

3. Connectivity: The medical sensors were isolated from user interfaces previously. Later, the sensors are capable for interfacing with external devices via wired like USB, Ethernet or RS 232. But, currently the medical sensors are capable to incorporate with wireless connections for short-range like Bluetooth, Zigbee etc. to nearby PDA, Smartphone or PC. The long-range service is also done by Wi-Fi or cellular communications for

communicating with cloud-computing services. This real-time medical sensing facility is available by portable and ambulatory sensors with wireless connectivity to cloud computing resources.

Wireless Sensor Platforms: Current technology offers the embedded platform that integrates processing, storage, sensors and computing. This embedded platform is largely available for healthcare applications by motes (specialized wireless sensing platform). This mote is actually flash memory that contains 8 or 16 microcontrollers, RAM for program storage and ROM for external storage and runs about 10MHz [15]. This hardware is again advanced by embedded operating system [16], networking protocols [17] and component-related programming language. The combination of mote and Smartphone platform provides different categories of healthcare application. The Smartphone provides more powerful computing, higher network bandwidth and larger data storage.

III. Basic Technologies of Medical Applications.

With the advent of latest technology as well as exploitation of wireless medical application; the large-scale wireless and mobile computing solutions in healthcare application are expanded. With the help of cellular 3G, WIMAX, caregivers; the vital information can be accessed at anytime and anyplace with the healthcare networks. The innovative medium of data transfer in healthcare application is developed as Bluetooth, RFID, ZigBee and WSN ETC. The various technologies are described as follows,-

WLAN: This technology arrived in 1997 as IEEE 802.11 standard. The initial version of this standard is IEEE802.11a and IEEE802.11b has capacity of 100 ft and 350 ft respectively. Then the Wi-Fi alliance started work as wireless based devices. Later, IEEE802.11g standard is developed in 2003 with 54Mbps data capacity as well as 2.4GHz band of 350 ft outdoor range. Again, IEEE802.11n has developed with higher throughput rate of 200Mbps and IEEE802.11i has arrived with enhanced security feature in 2004. The another standard IEEE802.11s is released in Mesh Network.

WIMAX: It is wireless MAN standard based on the IEEE 802.16 standard that has the capacity up to 50 km data transmission with high data rate up to 70 Mbps. It has strong security of mobile data transfer up to 150km/hour. The advanced radio technologies like QoS framework, AMC (adaptive modulation and coding), ODFM (orthogonal frequency division multiplexing) are incorporated with it.

WPAN: This technology arrived with ZigBee or Bluetooth standard for physiological monitoring based on the motes. Besides patient health monitoring, this standard is also able to track patient's location wise like mass casualty incidents too. The WPAN ZigBee standard based on IEEE 802.15.4 is an ultra-low power and low data rate that is used for controlling and monitoring applications.

WBAN: The body-integrated network based on ZIGBee or UWB standard that is developed as small, lightweight and ultra-low-power monitoring device. It is combined with physiological sensors that are helpful to monitor critical conditions of patients in hospitals. This network is also capable to transmit patient's vital conditions outside hospitals to the specialists through internet in real-time. The data transmission is done by intelligent sensors to the server that is running on a laptop, PDA or 3G Smartphone.

RFID: The RFID chip is used first in Food and Drug Administration in October 2004. Since, the various U.S hospitals were using this technology for monitoring medical equipments as well as positioning patient and hospital staffs. By applying wearable vital sign sensors with it, the physiological status of patients can easily achieved.

Cellular system: This system with the standard like 2.5G, 3G and beyond 3G used to gather information from sensors, servers and monitoring devices that improve the telemedicine service. It has the main feature of connecting heterogeneous network and offers flexibility for end-to-end telemedicine service [18].

IV. METHODOLOGY OF WIRELESS SENSOR NETWORK

Using wireless sensor network in medical industry, the following three terms are considered,-

1. **Telehealth**[19] is a very demanding area at today that provides health care services, health monitoring, health related information services as well as health care education remotely. The doctor consultation, remote monitoring of patient's vital parameters, e-prescription by doctor as well tracking remote patient's conditions periodically are done by this method.

2. **Telecare** [20] is the facility by which patient can stay safe in his/her home. This technology with the help of wireless sensor network provides continuous remote monitoring of patients as well as real time alerts in case of emergency to the hospital.

3. **Telemedicine** [21] technology provides remote health care and health education facilities through electronic communication and information technology. This technology offers video consultation with doctor, patient's evaluation remotely and digital transmission of patient's records.

The body area networks can be in three following trends,-

1**. On-body implants**: These sensors are naturally placed on the patient's body to monitor vital parameters like temperature, ECG, blood pressure etc. [22]

2. In-body implants: These sensors are implanted in the body to monitor the activity of the transplanted organ or activity of any affected organ. An in-body sensor for cardio, neural activities and artificial eyes are developed by Rogers's research group [23].

The Wireless Sensor network is discussed earlier section and it is very much helpful for continuous monitoring of physiological status of patients. The BAN (Body Area Network) paradigm can be classified into three different paradigms,-

1.1 Static patient with BAN but doctor terminal is mobile: In this paradigm, doctor used to come to patient's ward to check patient's status as patient is static. When doctor comes then the doctor's terminal collects updated information from the patient BAN and doctor's terminal is updated by these records.

1.2 Static doctor terminal but mobile patient's terminal: This paradigm is useful when the out-patients come to the hospital for their check-up. When the patient comes, the installed BAN exchanges data from patient's body with hospital's network.

1.3 Both doctor and patient terminal is mobile: This paradigm is useful when the doctor and the patient both are mobile like doctor's visit in rural areas of health camps periodically. In the camp site, the installed node collects data of the patients separately. When the doctor comes in the health camps at the next visit, doctor's terminal collects patient's data from the installed node and updated. So, doctor can detect and monitor patient's status with the help of this BAN easily.

V. EXISTING WEB BASED WWBAN ARCHITECTURE

The web based WWBAN (Wearable Wireless Body/Personal Area Network) is a multi-tier Architecture that is shown in the following figure,-

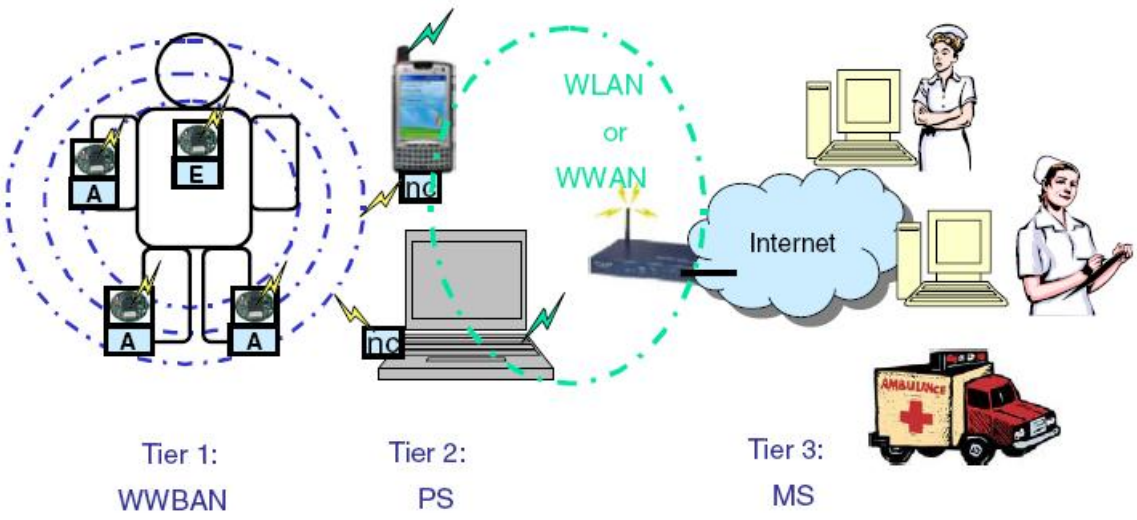

Fig 2: WWBAN integrated into a telemedical system

The tier1 contains the different medical sensor nodes that are embedded with WWBAN. These sensors are capable to sense different physiological signals of patients like ECG can detect and monitor heart activity, EMG can monitor muscle activity, EFG monitors brain activity, blood pressure sensor monitors blood pressure, and breathing sensor monitors respiration as well as motion sensor can be used to detect patient's status and activity. Tier 2 contains a personal server where the application is running on a PDA (Personal Digital Assistant) or Smart phone or PC. The personal server bridges the gap between the wireless medical sensors, user and hospital servers. Here, the WWBAN provides network configuration like sensor node registration, initialization, customization and setup of a secure communication. The information is received by PS, first determines the patient's health status and provides feedback through a user-friendly interface and stores the information into a local server. When, the communication channel for sending data to medical server is free, the information is sent to medical server and stored onto it through online. The tier 3 contains a medical server that is accessed through internet. Here different servers are also attached for emergency services, informal caregivers etc. The medical server is also able to process data from PS and sends report to the PS with recommendations. If any abnormal condition occurs, the service of medical server can also send alert message as well [9].

VI. TECHNOLOGICAL CHALLENGES

Using wireless technology in medical and healthcare application has different advantages but there are also several technological challenges in this field. The different technological challenges can be different network bandwidth, communication protocol, node failure, link failure, transmission delay, lack of data integrity, delay for fault-tolerance etc. Data availability and reliability are the most important considerations in healthcare application. For example, in case of high-risk patient the quality of services as well as wireless node connection and link quality should be carefully taken. The wireless technology should be used properly to maintain patient's data private and secure and must be available by authorized persons.

The following technological challenges are found for WSN using in health monitoring application,-

1. Trustworthiness: Using wireless sensor network, the system reliability and data delivery sometimes hampered. For example, to measure the level of oxygen in patient's blood in pulse oximetry application can vary every 30 seconds. Different researches showed that, these measurements can vary by 4% from the actual oxygen concentrations in the blood [24]. In case of RF (Radio frequency) communication, different harshness is found. For example, the radiation is hampered by the metal door and dividers mainly in operation room. Currently, Ko et al. found that packet losses in RF by IEEE 802.15.4 standard (WiFi networks, Bluetooth, cordless phones etc) is higher in hospitals other than indoor regions [25]. Sometimes, the quality of data from wireless sensing system compromised by sensor malfunctioning, faults and user actions. In case of Smartphone based system, the quality of data is hampered too. As, medical staffs are not aware for handling the sensors properly, so data quality is lost. Another challenge is that, the sensors continuously collect physiological data under some certain condition; the collected data may be populated by different types of artifacts mainly heart rate and respiration measurement are affected.

2. **Privacy and security**: In case of wireless sensor network, different types of context like space, physiological sensing parameters, time are considered. As, these contexts are collected and evaluated in real-time. So, these contexts should be protected and secured.

3. Due to lack of on-line consistency checking, sometimes right users cannot access right data in real-time. When the system interacting to each other in living facilities, hospitals and other pharmacies; the privacy problem may occur.

4. Due to lack of high-level aggregation requests like maximum and minimum reading value of sensing data, the privacy may be hampered in wireless communication.

5. Besides the privacy of data, security is also very important. For proper maintaining the security issue, different techniques can be chosen like configuring specific medical actuators.

6. **WSN can experience a Fingerprint and Timing-based Snooping (FATS) attack**. This attack can be fixed but it is cost-effective.

7. The security attack cannot be resolved in low-power WSN platforms due to resource constraints of devices, minimum accessibility of sensors as well as unreliable nature of Wi-Fi communication.

8. As the devices are small with limited battery lifetime, typical wireless sensor nodes have low power and limited resources.

VII. PROPOSED SYSTEM

In near future, the more sensors can be developed to monitor different physiological parameters of the patient that will be very much helpful for instant treatment of the patients by the doctors. This feature actually increases the efficiency of the wireless monitoring of the patients in biomedical region.

In the present WSN system, multiple actors are present to access multiple data due to lack of biometric identification. So, implementing proper biometric identification algorithm, right actor can access the right data of the patient that is necessary for removing medical errors as well as properly diagnostics in future. For increasing quality of data, dedicated sensors with data association algorithm should be developed.

When the data integrity is an important factor in a situation then some functionality may be disabled. Certain types of privacy mechanism can be implemented in future like patient can hide the monitored data of some sensors until it is necessary for diagnosis or emergency situation [26].

Using the WSN, the following proposed systems can be developed in future,-

1**. Rural healthcare service based on WSN or Mobile BAN:** The block diagram of this proposed system will be as follows,-

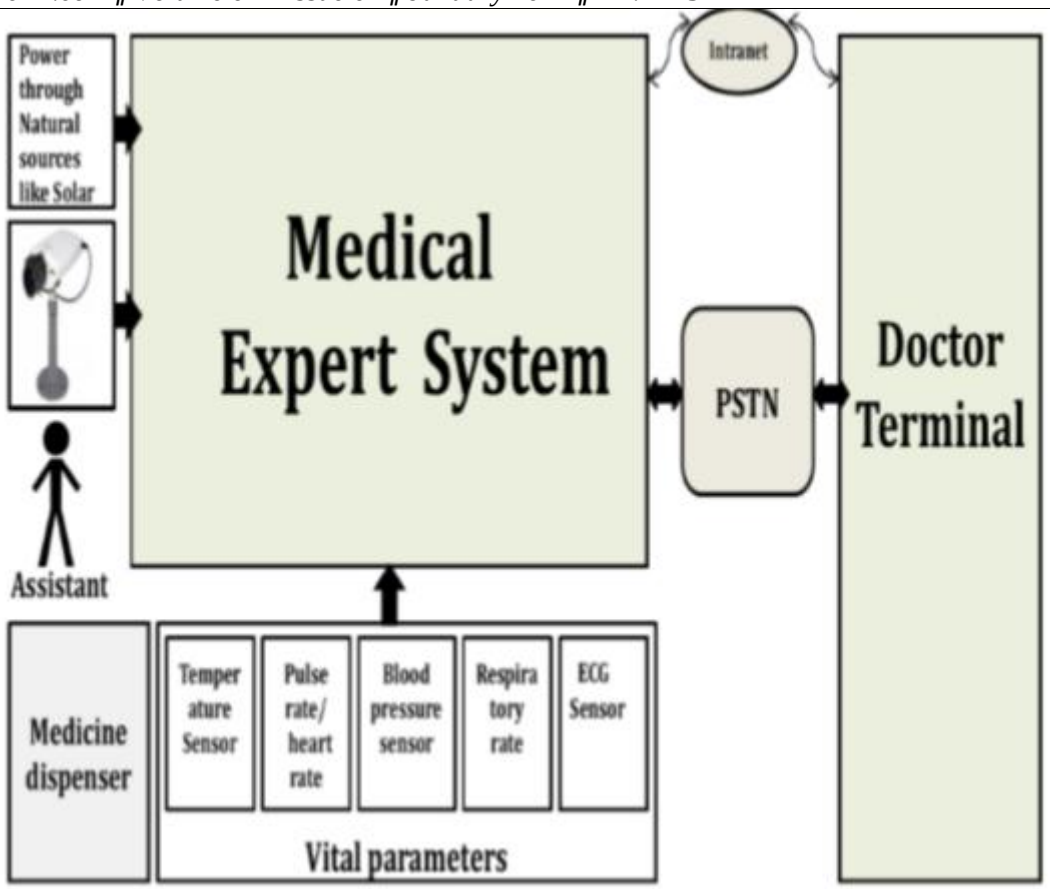

Fig 3: Mobile BAN system

The above system will be applicable for rural based health monitoring and treatment. Patient when goes to check up at mobile health care, the assistant attaches the sensors onto the patient's body to collect data of various parameters. The machine is attached with different types of sensors for measuring various parameters. If patient have normal diseases like fever or cough then Medicine dispenser service will offer the appropriate medicine. If any abnormal measure is found, then machine displays recommendation to the patient for doctor's visit as well as the assistant can connect with the PSTN network to call doctor. In this way, after completing all patients' data in a village, the healthcare personnel can move to another village with this mobile BAN.

2. Web based expert medical system: Each patient has BAN implanted on his/her body and connected to a central system through internet. After collecting all parameters of the patient, stored into the central server with respect to patient ID periodically. The central server contains the medical software that checks any abnormal condition of the patient. When any abnormalities are found, the server sends SMS or e-mails to the doctor's terminal as well as sends alert message to the patient's mobile and e-mail. The doctor's PDA or terminals are associated with the server. When the doctor wants to check any patient's data, he/she put the patient ID in his/her terminal and checks all status of the particular patient as well as doctor can give any advice for the condition that is stored in the server of that particular patient. After logging with Patient ID, the patient can check the doctor's advice from patient's terminal. So, the central server communicates doctor with patients. The patient can access his/her details information from the particular URL.

VIII. CONCLUSION

Wireless sensor network has great value in healthcare application as well as health monitoring system for the benefits of patients, medical staffs and above all society. This system is able to perform continuous health monitoring, detection of any abnormal condition, knowledge acquisition and recommendation by data mining of all collected data. The body area network is very much effective for monitoring the patient's data using various sensors and communicating them with the doctor and it can be placed at patient's house or hospital. The WSN system can connect the central server remotely to provide wide facility in the medical service for hospitals. This review paper discussed the basic wireless technologies used in medical applications,

the paradigms used for WSN, the overall body area network system architecture as well as web based system architecture and different technological challenges. By overcoming the technological challenges, the future development of WSN in health monitoring application are also proposed. By strengthening the privacy and security issue of WSN, the future devices are proposed that are very much helpful in real-time health application by providing quality of data. The further innovation should be by improving the Quality of service in wireless communication, security enhancement, interface and interoperability standardization as well as reliability of sensor nodes. Two new systems like web based expert healthcare system and rural healthcare service using WSN are proposed in future development part. In future, with the integration of large-scale system, the web based unsupervised healthcare application can be developed as well as the interconnection between gateway and remote server by GPRS communication extend the coverage of the healthcare system.

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