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Design of Medical Applications Using Wireless Sensor Networks

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Abstract: **- The advancements in large scale integrated technology and communication technologies have resulted in the development of low cost and small size wireless sensors. They can be even injected into human body for health care. This development has put enormous impact on medical healthcare scenario. It became easily possible to replace the traditional equipments and procedures with small sized sensors. Wireless Sensor Networks is very much useful in various 'Medicare' applications. The involvement of Wireless Sensors provides all-time monitoring to the user and either avoids the dangerous situation or is capable to take appropriate actions in case of emergency. This paper provides an overview of the challenges in the design of wireless sensor networks for medical applications. The major design challenges such as delay, security, privacy, accuracy and reliability of data, in these applications are explored with appropriate solutions.**

***Index Terms*— Wireless Sensor Networks, Medical Healthcare, Wireless Body Area Networks, Corporate Social Responsibility.**

I. INTRODUCTION

The intervention of Wireless Sensor Networks (WSN) starts in the human life when defense people have involved this technology to achieve defense related objectives. Since then it has revolutionized human life and currently its existence can be sensed in every field of life. The continual efforts of researchers to boost the integrated technology and communication techniques make it possible to develop economical sensor nodes with reduced size and increased intelligence for effective healthcare application. Wireless sensor network applications can be found for monitoring hostile environments such as forest fire, monitoring in household items and in industries to obtain high quality control. In advance medical science the WSN has very high impact. Regular visits to their doctors can be avoided, since doctors can get information about patient's health without their physical examination. The bulky medical equipments are replaced with tiny sensors. They can also be injected into human body. WSN have made it possible to acquire real time medical conditions directly from patient's body and record the data for diagnosis. The continuous monitoring services to patients suffering with chronic diseases can be provided. Any aberrations to the emergency directly reported to services providers in real time. This results in comfortable environment to the patients at their residences. In cardiovascular disease if the patient has no care-taker around at the time of heart-attack, then it becomes more severe. The WSN technology in healthcare applications has decreased this severity to a large extent. The heart of the patient is continuously monitored by the sensors and doctors are alerted if any irregularity is sensed. A 'Wireless Body Area Network' (WBAN) is designed as a special purpose sensor network to be embedded in human body. It can operate autonomously to connect various medical sensors located inside and outside of a patient. WBAN provides portable applications that can move along with the patient or attached to them as un-obstructive wearable. The medical signals such as ECG, PPG, EEG, pulse rate, pressure and temperature are detected by sensors [1]. The WBAN transmit the data with local control devices which are either on patient body or at accessible distance. Then it communicated with remote destination to exchange data for diagnostic and therapeutic purposes. In emergency case, such as abnormal readings received by ECG, an alert is sent to the concern people. An appropriate immediate treatment is then started as per severity of the alert [2]. Quality service can be provided to patient in emergency with highly equipped WBAN. In this paper the impact of WSN in medical science by exploring various applications and highlighting the challenges and limitations of WSN in medical healthcare applications are explore. In section II, the applications of WSN, and in Section III, the major challenges and limitation of WSN in medical healthcare are highlighted and concluded in section IV.

II. WSN HEALTHCARE APPLICATIONS

In the applications of WSN for medical healthcare, this provides all time monitoring services to the user and takes appropriate action according to sensors. Since the sensor devices are implanted in the human body they continuously monitor the user against the disease. Monitoring sensors, local server and remote healthcare unit are the main parts of

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health care system. Figure 1 illustrates a general structure of these applications. The monitoring sensors are small devices such as wrist bands or pendants which sense the body and communicate the data to local server such as laptops or mobile phones or 'Personal Digital Assistant (PDA)' devices. The local servers store the data and communicate with remote healthcare unit time to time. Immediate alert is send to remote healthcare unit for emergency response if it senses any emergency as shown in figure 2. Three important applications such as monitoring patent with precarious diseases, Infants monitoring and remote care of elderly patients are discussed here.

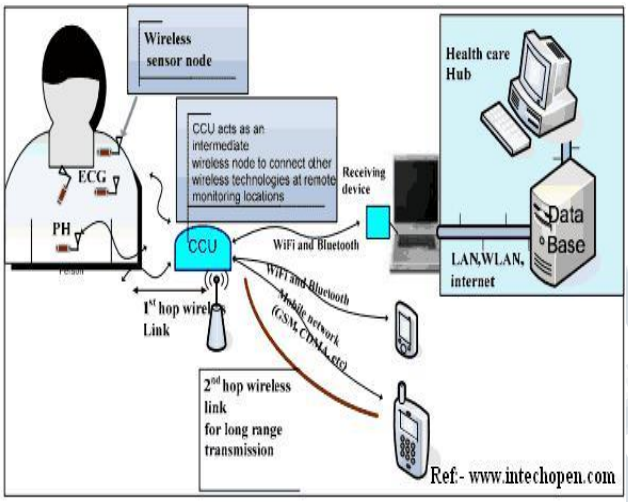

Fig. 1 General structure of healthcare applications

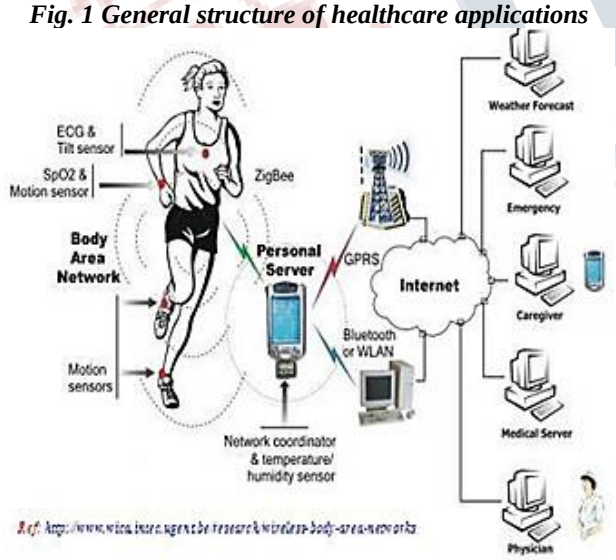

Fig.2 Wireless health care remote monitoring system

Monitoring patient with precarious diseases

In this applications patient has to be continuously monitor against the vital signs of disease and immediate report to local server. The local server processes the collected information and communicates with 'Remote Healthcare Unit' (RHU). The RHU consists of experts who evaluate the data take appropriate action. An immediate appropriate action taken can save the life of patient. In this type of applications monitoring electrocardiograph patterns (ECG), respiration rate, blood pressure, pulse rate and glucose level is the important parameters.

2.1. A Cardiovascular

Cardiovascular disease (heart attack) appears without any onset indications so that it is one of the leading causes of deaths in the world. However researches observe that cardiac rhythm disturbances can be taken as precursor to this attack [3]. In UK 39% of all deaths each year occur due to heart attack and about 30% of patients die before reaching hospital. Electrocardiogram is the most widely used technique for providing ambulatory cardiac monitoring for capturing rhythm disturbances. Cardio Net [4] a remote heart monitoring system, transmits ECG signals to local PDA device which are then sent to the central server using a cellular network. This application consists of three main parts; the small three-lead ECG monitoring device pendant around neck or on a belt clip, the local PDA as a local server and the remote monitoring centre. The monitoring device communicates with PDA (Host Node) through wireless link as shown in figure 3.

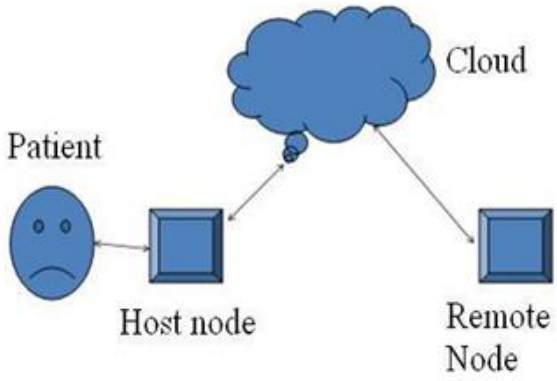

Fig. 3 Medical healthcare systems for emergency response.

The PDA device analyzes and stores the waveform and informs the remote monitoring system in case the variation in readings crosses the defined thresholds. The staff at the remote monitoring system takes an appropriate action on the received data. If they categorize it as routine event, then it is included in user's daily reporter they take immediate action for instance informing the physician and calling to the patient with precautionary instructions to follow if it is found serious.

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2.1. B Glucose Level Monitoring

It is estimated that around 24% of total population, in developed countries, suffers from diabetes and frequent 'Blood Glucose Levels' (BGL) monitoring is required to avoid further complications of the disease[5]. Glucose level monitoring system consists of sensors and actuators. An actuator is a device that takes action as commanded by sensor. A biosensor, implanted in the patient body, continuously monitor glucose level and transmits readings to local wireless PDA or other fixed terminal. When the sensed reading approaches a defined threshold, the insulin is automatically injected through actuator. Reliability is the main issue with these applications.

Infant Monitoring

The approximation shows that one in 2000 live born infants die as a result of cot death [6]. The WSN applications monitor infants against various conditions which can appear fatal at some stages for infants. They replace their parents care, for example they can monitor infant sleeping position during night. 'Sudden Infant Death Syndrome' (SIDS) is the leading causes of death for infants less than one year and only in USA approximately 2,500 infant's dies per year. An infant sleeping on their stomach is up to 12.9 times more likely to die from SIDS. The main causes of SIDS are still unexplained however researches have shown that one of the major causes of SIDS is by allowing infant to sleep on their stomach. Sleep safe [7] alerts parents when their infants are sleeping on their back. Three-axis accelerometer mote running with small 'TinyOS' program can be attached to the baby cloth. The single axis is used to sense the infant's position relative to gravity. The 'Mote' is oriented "face-up" and it can measure three discrete positions, back, side and stomach. This mote reads the infants position periodically and communicate with base station through wireless link for further process. The base station constitutes of a T-mote and laptop. It receives the data and analyzes the baby position. Parents can receive an alert from sensors to their cell phones if the baby is sensed on its stomach.

Elderly Patient Assistance

This category includes WSN healthcare applications which provide caring environment to the elderly patients at their homes and keep them away of experiencing any dangerous situation. Some of the applications are remote device control, smart nursing, medicine reminders, object location and medical data lookup. A network of sensors and actuators can monitor and assist elderly people in their day to day routines. Smart appliances make their lives organized by reminding them of their meals and medications. For example, the smart refrigerator informs the users if certain food is going out of date, and is capable of telling the user about the food he can take in line with known condition like diabetes [8]. These networks usually stores data and then exchange it with remote servers. In 'Aliment' consists of mobile body network and emplaced sensors. The mobile body network consists of sensors attached to the patient which provide activity classifications or physiological sensing such as ECG, pulse dosimeter and accelerometer [9]. This network can be tailored according to the patient needs. This network also contains gateways for communication with nearby WSN. The emplaced sensors are deployed in the living area sensing environmental phenomenon such as temperature, dust or light. These networks generate data and store it at local sink or send it to the back-end database.

III. DESIGN CHALLENGES AND LIMITATIONS

The main requirement in WSN is that, the size of WSN node must be small. A sensor node has limited processing capabilities and limited amount of energy so that there are so many challenges in designing perfect network for various applications. It is very critical to develop proper routing protocol for guaranteed communication from source to destination. Tiny size of sensor node puts limit on battery size so that overall system should be energy efficient and this is the big challenge for the design engineers. This section explores some limitations of WSN for medical healthcare applications.

1. Accuracy and Reliability

Reliability proposes high degree of accuracy so the sensors must be able to provide real time accurate information regarding the patient's health. If the patient's information is not accurate then it may result in improper treatment or even can lead to the patient's death. For example, in case of cancer detection application, system failure can lead to the incorrect reports. The sensor devices must be robust since they are left with the patients without all time monitoring [10].

2. Context Awareness

Context means the information which can be used to describe the state of an entity; the entity can be a person, place or physical object. In medical healthcare applications, it demonstrates the significance of associating physiological user activity and environment to the sensed signals of the user; the sensors must modify their behaviors in accordance with the user's situation and surrounding such as outside temperature, time of the day. For instance, if a body sensor detects a rapid increase in a patient's heart rate, it might be due to a change in patient's physical activity (such as exercise) rather than an abnormality in rhythm disturbances. There are several challenges the context-aware computing

faces in medical healthcare applications. Node failure or motion artifact may lead to noise in the sensor networks which may results in wrong sensor readings the patient may not get proper treatment. The context aware sensing algorithm must be able to reduce the effect of noise in sensor data. For long term pervasive systems, new contexts can added to the system. Therefore, it must automatically update new contexts and remain updated with old context to avoid re-learning [11]. Similarly, only the sensors relevant to the current context must apply with filtering the redundant and irrelevant sensor. Body Sensor Networks, with large number of sensors, provides numerous features while only a small subset of these features are relevant to recognize the context [12]. Therefore, the irrelevant or redundant sensors should be filtered out. Artificial Neural Networks (ANN), Bayesian Networks (BNs) and Hidden Markov Models (HMMs) are some of the context-aware sensing technique available to resolve this issue.

3. Comfort ability and Efficient Response

One of the most important issues is to make the applications comfortable and easy to use. The main purpose of these applications is to improve healthcare services without putting any effect on user's daily activities. Therefore, one of the major issues is to develop applications which are small in size and easy to use. The sensor devices must be lightweight, smaller in size, and easy to assemble by the user depending of health condition of the patient. The size of the device or complexity in its assembling or usage can result into complications in applications. Emergency alerts needs to be efficient in order for the provision of better and in time services [14].

4. Energy Consumption

Small integrated rechargeable battery is the only energy source for the sensor nodes. Node stops working as soon as the battery exhausts. In health care application sensor node are mostly implemented in the human body so that recharging or replacement of battery is very critical. It is observed that communication of data consumes more energy as compare to processing. The continuous monitoring operation of sensors is essential for healthcare applications so that energy efficient routing protocol is major issue. The techniques like 'duty cycling' and 'in-network processing' can be to reduce power consumption.

5. Fault Tolerance

A sensor node is considered to be faulty if it is giving results which significantly deviate from the results of the neighbor nodes [14]. Malfunction of the sensor devices itself, the harsh environment and intruder attackers are the varieties of faults tend to occur in sensor networks. A faulty sensor works but produces abnormal results. The network has to provide precise services even if some nodes fail to participate. So that more than one sensor nodes may have to use to collect data from patients body. In order to maintain a seamless provision of services, appropriate fault tolerance mechanism must be in place.

6. Privacy

There are many serious threats to the privacy of the user when the data travels through wireless media. End user privacy is one of the main concerns in WSN healthcare applications. In healthcare applications the privacy of patient's information is very important in particular case. On the other hand, it is always not possible to take the patients consents before sending the data especially in emergencies. The information can go to public domain and malicious users can misuse it. Proper procedures are required to store the gathered data and to select people who can access the data. Similarly, the users must be taken into confidenceabout these procedures.

7. Quality of Service (QoS)

The overall success of WSN in medical applications depends on reliability of system. Proper QoS mechanism must be implemented to make sure different functions working satisfactorily. For example, the most important traffic still has its QoS requirements fulfilled in case of network overload and finally that QoS mechanisms are able to adapt dynamically depending on the context. The major challenge in WSN healthcare applications is to minimize the transmission delay of various types of communications in the system. In WSN, data passes through various hops before reaching the destination. Sometimes, the hops are located in critical areas such as magnetic field or areas bearing interference of radio waves which can result into a transmission delay [15]. The proper synchronization can improve overall QoS in order to minimize the delay.

8. Security

Secure data communication is a major area of research in WSN applications. Wireless media is always more vulnerable than wired media for attackers. High level security is more important in healthcare applications since it can result in life threatening situations. Security has several levels in healthcare applications. The security threats can occur during routing the data where intruders may change the destination, can make routing inconsistent or even steal the data by eaves dropping the wireless communication media. The attackers can steal or modify the data routing through GPRS or similar networks. The criminal-minded attackers can track the user location or can keep an eye on user's activity. The attackers can fiddle with the data by forging alarms. They can also wage the 'Denial of Service' (DoS) and 'Jamming' attacks on the networks. 'Data

Encryption and Authentication' are major security techniques used for security provision. Data encryption techniques must be used for secured data transfer and legitimate devices must be allowed to create or inject data into the system. Encryption techniques are the best solution for high-level security.

9. Topology

The sensor devices are mounted on the human body that can be in motion. The routing topology of the network changes with patient's movement and may be dynamic all the time. These networks should be able cope up with frequent changes in the network topology and must be robust in nature.

IV. CONCLUSIONS

The technology improvement in wireless sensor and its networking technology has been resulting in various social applications which are making human life easier and comfortable. The applications of WSN in medical healthcare have put a massive impact on medical healthcare of patient's risks in emergency situations. It is the corporate social responsibility to provide friendly environment to patients at homes. The various design challenges in WSN are discussed in this article. There are many applications which can monitor patients and alerts physicians and emergency care providers if the patient is at risk. The small sized wearable sensor devices usually do not affect patient's normal routine. It very challenging to design appropriate sensor network to meet various needs health care applications. Major challenges include the provision of Security, Privacy, Accuracy and Reliability. In future due to heavy load on hospitals it is very necessary to improve atomization in health care applications so as to give better service to emergency patients.

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