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Evaluation of Performance Parameters of healthcare Monitoring System

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Abstract: - **Wireless Sensor Network (WSN) can be effectively used for continuous monitoring of patient in hospitals and in homes for elderly and baby care. For this the medical data in terms of vital body parameters of patient are to be collected. Various bio sensors such as temperature, heart rate and pulse rate are attached to the body of patient and data is collected and send via wireless sensor network. The efficacy of healthcare monitoring system depends on ease of operations and how efficient and accurate the data communication is. Many parameters are available to evaluate the performance of healthcare system based on WSN. This paper aims to study the performance metrics available and evaluate the performance of the system based on certain WSN metrics such as LQI, Packet delivery ratio, network throughput etc.**

***Index Terms*—** **WSN, Healthcare Monitoring System, performance metrics.**

I. INTRODUCTION

Due to noticeable development of wireless technology, wireless devices have infested the medical areas with wide range of capabilities.The focus is to reduce mesh of wires and provide ease and comfort to staff as well as patients.With the advances in technology and smart physical sensor node development, WSN nodes are becoming tiny, lightweightand lowcost. Therefore use ofWireless Sensor Networks (WSN) in healthcare monitoring is found advantageous over its wired alternatives.[1]Portable devices such as blood pressure, temperature and stress monitors using sensors are more power efficient integrated circuits and wireless data transferring have allowed the development of wireless body area networks (WBAN) for health monitoring. [2]. Due to advances in sensor networks and nanotechnology one can integrate number of biosensors such astemperature, blood pressure, ECGto monitor vital body parameters and environmental sensors likehumidity, light and also location sensorson a single board to form Wearable Wireless Body/Personal Area Network (WWBAN) [3]. The healthcare systems based on WWBAN are very useful for long-term and short term health monitoring which can generate instantaneous feedback to the user about the current health status and real-time or near real time updates of the user's medical records.

II. LITERATURE SURVEY

Many state of art WBAN applications are available in the literature.WBAN Based Healthcare System typically follows three Tier architecture explained below.
Architecture of WBAN Based Healthcare System.
Healthcare monitoring systems are typically based on three Tier architecture. Tier 1 consists of sensors design, Tier II consists of sending sensor data to room servers which collects data from all nodes. Tier 1 and 2 collect and process data and Tier 3 makes this data available to outside world via internet or mobile communication. Communication architecture of WBANs can be separated into three different Tiers as follows: [2][4]

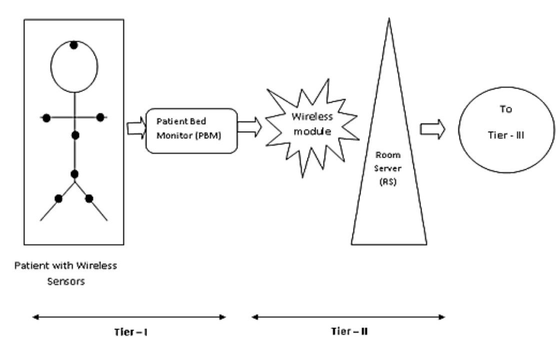

Fig 1.Three Tier Architecture of WBAN

Tier-1: Intra-BAN communication – communication of data of various sensors attached to the patient body and Patient Bed Monitor (PBM). The transmission range is in and around the human body within 2 meters.

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Tier-2: Inter-WBAN communication – This communication Tier is between the PBM and one or more access points (APs). This type of communication can be i)Infrastructure based where AP's are part of existing Infrastructure and AP's can act as database server or ii)Ad-hoc based architecture where AP's can be placed strategically in a dynamic environment to handle emergency situations.The coverage area of ad-hoc WBANs is from 2 meters to 100 meters, which is suitable for both short as well as long term setups.Objective of Tier-2 communication is to interconnect WBANs with various networks, inside and outside hospitals or home.

Tier-3: Beyond-WBAN Communication -Agateway such as a PDA can be used to connect Tier-2 and outside world viaInternet to Medical Server (MS). ThusInternet or a Short Message Service (SMS) can be sent to doctors or patients to notify the emergency status. Additionally, **Tier-3** allows restoring all necessary information of a patient on medical servers which can be used for their treatment.

Many bio sensors are available to work with Tier-1 of WBAN. Some commonly used sensors are described in Table 1[5].

Table 1: Type of sensor

Type of sensor	Type of Bio-signal	Type of sensor data
Skin/chest electrode	ECG	Electrical activity of the heart
Arm-cuff based monitor	Blood pressure (Systolic/diastolic)	Refers to the force exerted by circulating blood on walls of blood vessels especially the arteries.
Temperature probe or skin patch	Temperature	Body temperature
Piezoelectric sensor	Respiration rate	Breathing rate (inspiration and expiration per unit time)
Pulse Oximeter	Oxygen saturation (SPO2)	Amount of oxygen in patients' blood
Pulse Oximeter/ skin electrode	Heart rate	Frequency of cardiac cycle
Galvanic skin response	Perspiration/ skin Conductivity (sweating)	Measurement of sweating
Strip based glucose meter	Blood glucose	Measurement of amount of glucose
Skin electrodes	Electromyogram (EMG)	Electrical activity of the skeletal muscles
Scalp placed electrodes	Electroencephalogram (EEG)	Electrical spontaneous brain activity and other brain potential
Accelerometer	Body movements	Measurement of acceleration forces in the 3D space

Requirements of HCWSN Architecture:

A typical WBANarchitecture includes -(i)number of sensors able to measure vital body parameters and a small networkaround the body, (ii) a gateway or sink to connect to another network with some routing and data aggregation policies, (iii)Internet or intranet to connect with outside world , and(iv) medical server with GUI. Many authors identified the requirements of WWBAN for such applications.

(i)Light weight, reduced size, low powerconsumption, simplified integration into a WBAN,standards-based interface protocols, and patientspecificcalibration, tuning, and customization,With regard to the actual hardware, body sensorsmust besmall, thin, non-invasive, and wireless-enabled and must beable to operate at a low power level [6].

(ii) Certain Data encryption technique for sensitive medical data transfers.

(iii) Fault tolerance: in case of a sensor node failure,immediate neighbourhood can back-up and can take on the role of that node, so that criticalmeasurements are not missed,

(iv)Network quality of service (QoS): it is essential formedical data to be transmitted and received withouterror and in time.

Also to deploy WSN for healthcare monitoring system (HCWSN),it has to follow certain specific requirements. There are five main requirements that the architecture for a health care WSN must satisfy:

(1)Reliability-It is closely related to the ability to transmit accurate and miscellaneous data and following strict quality of service (QoS) requirements, in terms of low end-to-end latency andhigh packet delivery ratio (PDR).

(2) Energy Efficiency-Continuous or remote monitoring health care applications require careful energy management. Many sensors do not require external power as they use battery power. Also sensor networks can save energy by using efficient network design and various energy efficient scheduling algorithms. The energy consumption of these devices is to be minimized so that their lifetime can be extended.

(3) Routing- Data routing in HCWSN can directly impact important factors like reliability and fault tolerance. It affects the energy consumption of the system for communication.

(4) Node Mobility- It isthe ability to move around, for both, patients and caregivers. It requires the implementation of certain communication layer protocol which adaptslink quality and transmission delay.

(5) Timeliness- Transmitted information should be delivered on-time, especially in emergency situations. [7]

Many researchers have put their efforts to improve the performance of the above parameters. Many researchers have not yet found adequate solution for the aforementioned HCWSN requirements like reliability, routing, node mobility. There still exists a gap between thespecific requirements andexisting WSN technologies.

III. PROPOSED SYSTEM

Considering vast study on requirements of WHMS, some of the parameters are considered at the time for system design.

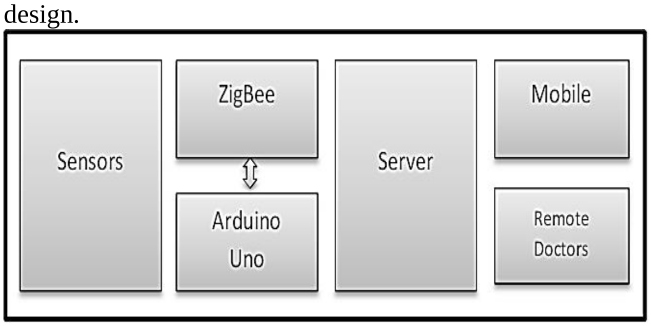

Fig 2. Block Diagram

In order to achieve the objectives of the project, the modules of the project are summarized as follow:

- Sensor module to acquire medical parameters from patients. The sensors used are more sensitive for more accurate results.
- Wireless sensor networks to transmit and receive data wirelessly in a long distance so that the system is portable and easy to be operated.
- Graphical User Interface at ICU server and main server used to display and update the parameters of patients in a real-time.
- GSM system to send alert messages to authorized user using mobile phone.

IV. IMPLEMENTATION DETAILS

These requirements are considered while designing our WSN based Healthcare monitoring system.

In actual implementation Arduino Uno board with ZigBee wireless communication shield and fourbio sensor nodes are used. Sensor used are-

Temperature sensor – LM 35.

Heart-rate and pulse rate sensor – LED / LDR sensor.

Stress sensors – Galvanic Skin Response sensor.

ECG sensor- AD 8232.

1. As the size of Arduino board and sensors is very small as compared to previously used bedside monitors, form factor is considerably reduced.

2. ZigBee WirelessCommunication is used to make the communication simpler, low cost, low data rate and energy efficient [8].

3. Number of sensors are increased therefore complexity of the system is increased.

V. MEASURING SYSTEM PERFORMANCE

The objective of our system is designing efficient Healthcare monitoring system based on the parameters mentioned earlier like efficiency, reliability etc. Therefore performance of the various system parameters is to be verified.

SwiFiNettestbed[9] is used for the verification of different wireless sensor network parameters. We have studied changes in various parameters values with respect to wireless sensor node, router and server. Different parameters are tested like -

– Network setup time and communication load.
– Network throughput.
– Packet delivery ratio.
– Bandwidth overhead.
– Hop to hop and end to end transmission delay.
– Packet latency.
– Link Quality Indication.

The experimental setup consists of server, router (relay node) and node. Node transmits sensor readings from connected sensor to server directly if within specific distance range. If relay node is present it connects itself to relay node and then transmits data first to relay node, which further sends data to server. We can measure various parameters in presence of relay node (router) and direct from node to server. Graphical representation of experimental results is shown below.

1. Packet Delivery Ratio:

The ratio of the data packets delivered to the destinations to those generated by source i.e sensor in this case. It is the fraction of packets sent by the application that are received by the receivers.

It is calculated as-

$$\mathrm{Pdr} = \mathrm{Pr}/\mathrm{Pt}$$

Where-

Pris total number of packets received at the server and Pr is calculated as-

$$\mathrm{Pr} = \sum_{i=0}^{n} \mathrm{Pn}$$

Pnis number of packets received from each node.

Pt is total number of packets sent by all nodes together.

Fig. 3 and fig.4 shows the readings of PDR before connecting to router and after connecting to

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router. It is observed from experimental values that PDR is increased if router is added in the system.

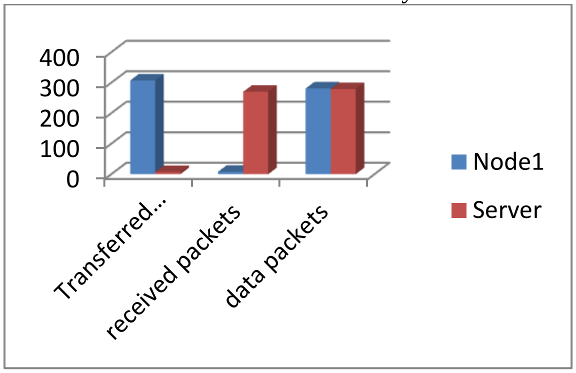

Fig.3: PDR: Node 1 & Server

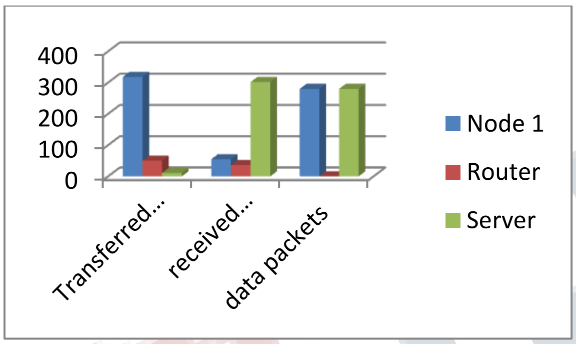

Fig 4: PDR: Node 1, Router & Server

2. LQI

Fig. 5 and fig.6 shows the readings of PDR before connecting to intermediate node like router and after connecting to router.

It is observed from experimental values that LQI is improved if router is added in the system after specific distance.

3. Average Transmission delay:

Indicates how long it takes a packet to travel from the source to the application layer of the destination. i.e. the total time taken by each packet to reach the destination. Average End-to-End delay of data packets includes all possible delays caused by queuing delay at the interface, retransmission delays, propagation and transfer times.

Average transmission delay Tad is calculated as

$$Tad = \frac{\sum_{i=1}^{N}\sum_{i=1}^{n} Td}{Pd}$$

Where

Tad : sum of transmission delay of all packet sent by node added for all over N nodes

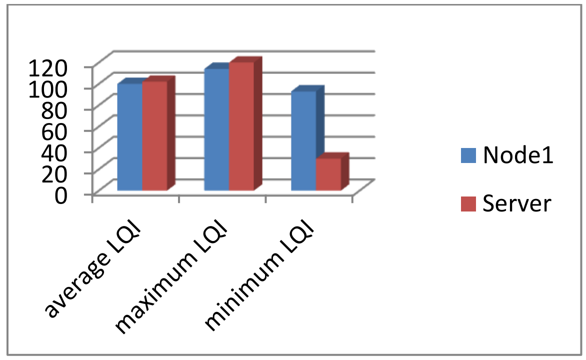

Fig.5: LQI :Node 1 & Server

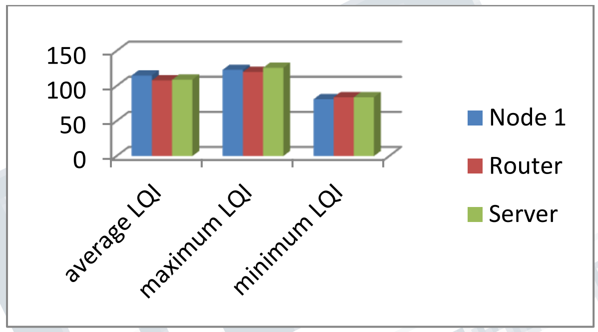

Fig 6: LQI: Node 1 , Router & Server

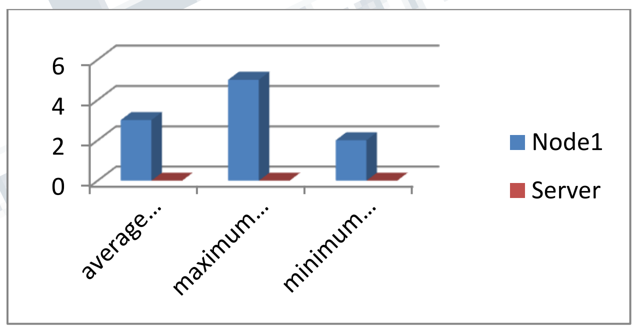

Fig.7: Node 1 & Server

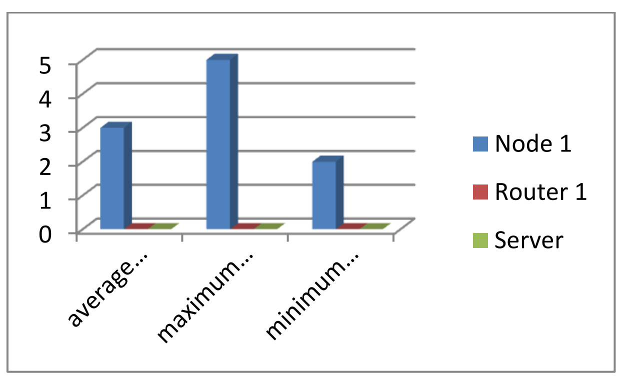

Fig 8: Node 1, Router & Server

Fig 7 and Fig 8 shows the transmission delay in absence of intermediate node and in presence of any intermediate node like router

It will be used to compute various parameters such as network throughput, packet delivery ratio, hop to hop and end to end transmission delay, packet latency, Link Quality Indication and distance and signal strength at the time of actual system implementation. We can evaluate the performance of the system for various values.

VI. CONCLUSION

Wireless healthcare monitoring system design proposed here depictsproperties like minimal weight, miniature form-factor, low power operation and patientspecificcalibration. It is low cost and easy to operate.As the size of the board and sensors is very small as compared to previous Arduino Uno boards, form factor is considerably reduced. Low cost ZigBee communication chip is used for wireless communication to make the communication more reliable by increasing its availability.Many network communication parameters for wireless sensor networks like transmission delay, LQI and packet latency in various situations are also observed to make system more efficient.

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