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Performance Analysis of a Priority Based Buffer-Aided Relaying System for WBAN

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***Abstract*—**Wireless Body Area Network (WBAN) is a collection of low power sensing devices which are either implant inside human body or on-body devices. This network helps to transmit vital parameters of body over wireless network to the remote server. Among different categories of body parameters some of are supposed to be vital and required to transmit faster than others, so that necessary actions can be made in time. In this paper we have studied various literatures on conventional WBAN, IoT based WBAN, Buffer-Aided Relaying Frame work etc. and proposed a model to handle priority based on-body sensor data(e.g. Heart Rate Data, Blood Sugar Data and EEG data) along with relaying node with buffer. The priority level is analyzed by a priority analyzer node. This model is simulated using Java Modelling Tool (JMT) and various performance matrices like Response Time, Throughput, Queue Time, Utilization, etc. are analyzed in terms of simulation graphs. Our model out performs for prioritized data than the non-prioritized data as represented in the result section.

***Keywords*—**WBAN, Relay-Buffer, QoS, Throughput, Response Time

I. INTRODUCTION

With ageing of the population, existing medical resources cannot satisfy future healthcare demands of seniors and patients. Resources are limited and it is impossible for most patients to afford long-term hospital stays due to economic restrictions, work, and other reasons, even though their health status must be monitored in a real-time or short periodic time mode. As a result, wireless monitoring medical systems will become part of mobile healthcare centers with real-time monitoring in the future. The problems of chronic diseases, medical quality and the strained healthcare infrastructure have become an important challenge for the long-term envelopment of the world. To improve the medical quality and reduce the healthcare cost, it is a matter of the utmost urgency to use information technologies to solve the current medical problems. Healthcare Internet of Things (IoT) have facilitated the development of mobile-health systems that support gathering, delivery, and retrieval of medical information [1-2]. Recently, wireless body area network (WBAN), which has been reported in IEEE 802.15.6 [3], is considered as a new technology for mobile health applications to implement the medical devices either Implanted in or placed on/around the human body. A typical WBAN framework, as shown in Figure.1, consists of many low-power medical devices to measure biological parameters from the human body, e.g., emergency electroencephalogram (EEG) and electrocardiogram (ECG) data. More specifically, these useful biological parameters are first collected in an on-body device (i.e., the target hub), e.g., personal digital assistant (PDA), and the patient can know his/her condition in real time. After that, the target hub transmits these parameters to the remote off-body devices (e.g., monitoring central) through mobile communication network or Internet. In this sense, the doctor can observe the patient's condition in time and provide the patient with precise treatment. Unlike through-the-air wireless communications, the implant medical devices encounter many challenges because living tissues are considered as part of its transmission channel [4]. First, since the human body is a hostile channel to high frequency electromagnetic signals, the signals propagation is attenuated considerably. Second, the on-body devices should guarantee stringent-miniaturization and quality-of-service (QoS) provisioning.

Among all the challenges, how to guarantee the QoS for medical applications is considered as the most important issue [5]. It is obvious that equal-importance data transmission for the on-body device WBAN doesn't satisfy different classes of medical data, which includes one class of emergent data and multiple classes of non-emergent data. The emergent medical data should be transmitted in a highest-priority (HP) level, while the non-emergent medical data should be differentiated according to different application purposes. For instance, the on-body device like EEG sensor, Heart rate Sensor, Blood Sugar Sensor attached

to the patient's body collect the real time data and relay to the server/sink through a relay buffer according to their priority level in the form of aggregate data packets.

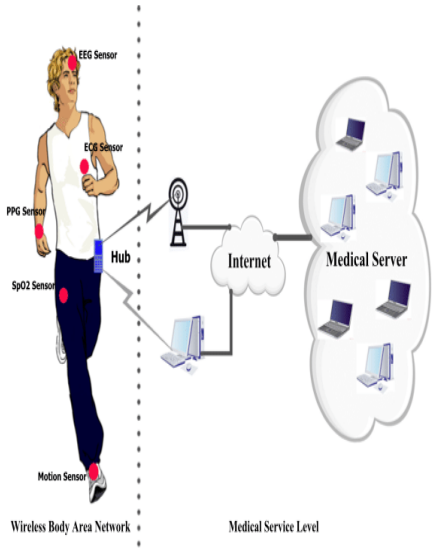

Figure 1. Conventional WBAN

The drawbacks of implant WBAN is given in [1]. First drawback is the data collected for simulation from some implant devices fixed inside the human body which causes very risky factors for normal life of human beings. Second drawback is the priority checking of data is decided by the implant devices using some algorithms which is not acceptable. Third drawback is when High priority data will generate by implant devices then it will broadcast by all relay node which will cause problems for low priority data and all for other priority data's generated on same time. Another important drawback is it supports direct source to sink transmission which may cause loss high priority data at any stage. All the above drawbacks may hamper the QoS of data transmission from source to destination.

The goal of this paper is to evaluate the QoS-aware relay buffer in relay framework of On-Body devices in WBAN. Apart from the system frame work, the algorithms like Non-Preemptive and Non-preemptive(Priority) are implemented for the real time transmission of data packets in multi-relay WBANs are proposed and their corresponding performance is investigated in terms of system throughput, utilization, response time etc. . Simulations are performed using JMT (Java Modelling Tool) simulator and its results presented. Here, proposed Priority based WBAN provides better performance than the traditional buffer-aided relaying framework for implant WBAN [1].

The rest of the paper is organized as follows. In Section II, we reviewed the recent literatures on the advances of WBAN technologies and implementations of buffer-aided relay mode data transmission from implant devices in patient's body. In Section III, we have proposed a model for data transmission using buffer-aided multi-relay WBAN with a priority fixing flexibility that able to transmit high priority data to the server/sink faster than low priority data. Also we have simulated the model using JMT. The performance indices are evaluated in terms of simulation graphs are presented in section IV. In Section V, the paper is concluded.

II. LITRETURE REVIEW

The Internet of Things, in short IoT, is used to design a body sensor network (BSN) in which sensors can be handled and monitored through the Wi-Fi access, wherever the location may be. Now, what is meant by IoT? A new technological network of physical devices, vehicles and many other items which eventually gained attention in cyber-physical systems is the Internet of Things. The computing system that is attached to electronics, software sensors, actuators and network connectivity makes the collection and exchange of data easier.

In paper [1] as per the author(s) wireless body area network (WBAN) comprises many low-power devices in, on, or around the human body, which offers a desirable solution to monitor physiological signals for mobile-health applications. In the implant WBAN, an implant medical device transmits its measured biological parameters to a target hub with the help of at least one on-body device(s) to satisfy its strict requirements on size, quality of service (QoS, e.g., reliability), and power consumption. Here the author(s), first review the recent advances of conventional cooperative WBAN. Afterwards, to address the drawbacks of the conventional cooperative WBAN, a QoS-aware buffer-aided relaying framework is proposed for the implant WBAN. In this paper hierarchical modulations are considered to fulfil the different QoS requirements of different sensor data from an implant medical device. Author(s) also follow some new transmission strategies for the buffer-aided signal-relay and multi-relay implant WBANs. Simulation results show that the proposed cooperative WBAN provides better performance than the conventional cooperative counterparts.
In paper [6] the author(s) aim is to minimize in-body sensor node energy consumption and to prolong the network lifetime by utilizing a relay strategy based on the proposed flexible quality of service (QoS) radio frequency communication module and advanced In-to-out body path loss (PL) model. Author uses a algorithm and investigated in which the relay nodes with lower energy consumption and minimum distance to the coordinator will be chosen in each round. In this way, time division multiple access (TDMA) can be investigated to schedule data transmission from implants to the corresponding relays, and thus minimize the overall length of communication links. Moreover, a linear programming network lifetime model is proposed along with

various subjective functions. Simulations are conducted on a proposed topology network assuming two commercial transceivers. Results show that the existing two-relay based protocol achieves higher transmission data rates due to the availability of redundant communication pathways. However, the proposed incremental relay based cooperative routing protocol outperforms the existing two-relay based scheme in terms of total network lifetime, overall throughput, average power consumption and propagation delay.

In paper [7] According to the author(s) Internet of Things (IoT) is the new technology which includes the collection of Sensors, Actuators, processors and other development boards (e.g. Raspberry pi, Arduino etc.) to collect the data from different sources depending upon domain of application, process the acquired data before sending to distant cloud or mobile application depending upon the requirement. The most promising application of IoT is in the field of health care sector. In some countries, people still do not have access to quality health facilities owing to different barriers. The physical distance between patient and clinic is one of the foremost reasons. Here the author describes the application of IoT in health care domain and a system is proposed to monitor the ECG of the distant patient. Here the Bio signals are collected from the Body of the patient using ECG sensor and after the required processing using development boards, sent to distant cloud named as Bluemix which is owned by IBM, for further analysis by a physician or other authorized person. The Bluemix cloud uses MQTT (Message Queuing Telemetry Transport) protocol which is used to connect different types of applications and devices together across the globe. MQTT is a lightweight protocol which is developed for a machine to machine (M2M) communication.

In paper [8], As per the author(s) an active infiltration of information technology in the healthcare sector has led to a fundamental change in people's quality of life. In this regard, the security and safety problems of this technology using increase rapidly. This paper touches upon the issue of the healthcare Internet of Things (IoT) infrastructure failures of components and complete system. The purpose of the paper is to develop and research an availability model of a healthcare IoT system regarding failures of components. A detailed analysis of architecture of healthcare IoT infrastructure is given. The main causes of the healthcare IoT based system failures are considered. Much attention is given to developing and research of a Markov model of a healthcare IoT system considering failures of components. Some essential high-level requirements that such system must meet are presented. The analysis of obtained simulation results showed the rates that have the greatest influence on the availability function of the healthcare IoT system.

In paper [9], as per the author(s) Wireless Body Area Network (WBAN) is a kind of wireless sensor network (WSN) which can be wearable or implantable in the human body. WBAN is an emerging technology in the field of healthcare system. WBAN has received great attention due to its applications in the field of health, medical, entertainment services and many more. The main idea behind WBAN technology is to deploy them in the medical system to replace wires with the help of sensor nodes implanted into the patient's body or placed around the patient body. Not only it gives more comfort to the patient, but also patient can be treated remotely by the healthcare system staff. It is very helpful to the elderly people or people with any disability to provide medical facility at home or in any emergency condition. Here the authors have carried out survey of various existing approaches of WBAN and describe the future scope for further research in the field. The literature survey depicts that the existing schemes can be further modified to devise more reliable solutions for WBAN schemes.

In paper [10], the author(s) presents a hybrid wearable sensor network system towards the Internet of Things (IoT) connected safety and health monitoring applications. The system is aimed at improving safety in the outdoor workplace. The proposed system consists of a wearable body area network (WBAN) to collect user data and a low-power wide-area network (LPWAN) to connect the WBAN with the Internet. The wearable sensors in the WBAN are exerted to measure the environmental conditions around the subject using a Safe Node and monitor the vital signs of the subject using a Health Node. A standalone local server (gateway), which can process the raw sensor signals, display the environmental and physiological data, and trigger an alert if any emergency circumstance is detected, is designed within the network. To connect the gateway with the Internet, an IoT cloud server is implemented to provide more functionality, such as web monitoring and mobile applications.

In paper [11], a novel cloud-based WBAN health management system is introduced. This system can be used for people's health information collection, record, storage and transmission, health status monitoring and assessment, health education, telemedicine, and remote health management. Therefore it can provide health management services on-demand timely, appropriately and without boundaries.

In paper [12], the author(s) first present the evolution of the single WBAN concept to the cooperative network of multiple WBANs, giving rise to the BBN concept. A synopsis of the WBAN and BBN respective standards and applications is given, and the emerging BBN challenges are highlighted. Then, author present and discuss the existing WBAN

proposals, especially the candidate WBAN protocols that could be adapted and used in BBNs, focusing on four intrinsically related axes of great importance for BBN design: energy efficiency, mobility prediction, quality of service (QoS) and security. Further BBN open issues are also investigated, namely, the wireless propagation between humans carrying wearable devices, the interference, storage and privacy issues as well as the heterogeneity of BBN devices and traffic.

In paper [13], according to author(s) Wireless Body Area Networks (WBANs) deal with variety of healthcare services with diverse Quality of Service (QoS) requirements. However, QoS handling is a challenging problem in such networks. QoS related problems can be addressed from different layers in the networking protocol suite. Here the author analyzes the QoS requirements of WBAN, identifies the requisites of QoS handling system, and outlines the trends that are being followed for its advancement with focus on QoS issues at MAC layer. Author(s) reviews some prior works, compare them, and analyze the current research concerned with problem of providing QoS in WBAN.

In paper [14], an analytical and accurate in-to-out (I2O) human body path loss (PL) model at 2.45 GHz is derived based on a 3D heterogeneous human body model under safety constraints. The bit error rate (BER) performance for this channel using multiple efficient modulation schemes is investigated and the link budget is analyzed based on a predetermined satisfactory BER of 10^{-3}. In addition, an incremental relay-based cooperative quality of service-aware (QoS-aware) routing protocol for the proposed I2O WBAN is presented and compared with an existing scheme. Linear programming QoS metric expressions are derived and employed to maximize the network lifetime, throughput, minimizing delay. Results show that binary phase-shift keying (BPSK) outperforms other modulation techniques for the proposed I2O WBAN systems, enabling the support of a 30 Mbps data transmission rate up to 1.6 m and affording more reliable communication links when the transmitter power is increased. Moreover, the proposed incremental cooperative routing protocol outperforms the existing two-relay technique in terms of energy efficiency. Open issues and on-going research within the I2O WBAN area are presented and discussed as an inspiration towards developments in health IoT applications.

III. System Model and Simulation Setup

A. System Models

In this paper we have consider three on-body sensors 1) Blood Sugar Sensor,2) Heart Rate Sensor, 3) EEG Sensor as the source of data production implemented on the patient's body. There is a flexibility of fixing priority level in each of the on-body devices for data transmission according to the requirements of patients. Our proposed model consist of two parts 1) Priority analyzer 2) Buffer-aided relay nodes.

Priority analyzer (PA) is responsible for receiving the data from the sensor nodes (both priorities and non-priorities data) and forward it to the relay nodes. In a normal situation the sensory data are transmitted through all the relay nodes to the server/sink. But when a priority data arrives it will transmit on non-preemptive priority basis. The PA is a server without any buffer and responsible for identifying prioritized data source. Buffer-aided relay nodes are the stations with processors and buffers. In our model we have considered three relay nodes with capacity of six number of buffer spaces in each. Relay buffer one and two are based on non-preemptive scheduling queueing strategy whereas relay buffer three is based on non-preemptive (Priority) scheduling queuing strategy.

The arriving request from different on-body sensors follows a poisson's process with equal arrival rate. The inter arrival time are independent an identically distributed exponentially with mean value ten for each. The service rate of PA and relay nodes are exponentially distributed with mean 0.8 and 1 respectively. The requests are accepted by the PA and relay nodes and processed on First in First out (FIFO) basis.

B. Simulation Setup

To simulate the WBAN network several simulators are developed e.g. Ommnet++, NS2, etc. But to study the internal behaviour of a buffer-aided relay node no dedicated simulator is present till now. The queuing behaviour of the relay nodes is the focused points to study the performance factors of the proposed model. For this reason we use JMT for the performance evaluation of the proposed system. The simulation setup is presented in Figure.2. All the simulations are performed on PC with following parameters: Processor-2.9 GHz Intel core i5, 4GB memory, 500 GB HDD. Simulations started with three on body devices- Blood Sugar Sensor, Heart Rate Sensor, EEG Sensor with priority level fixed on Heart Rate. Other two are of equal priority. At the end of each simulation the output performance record has kept.

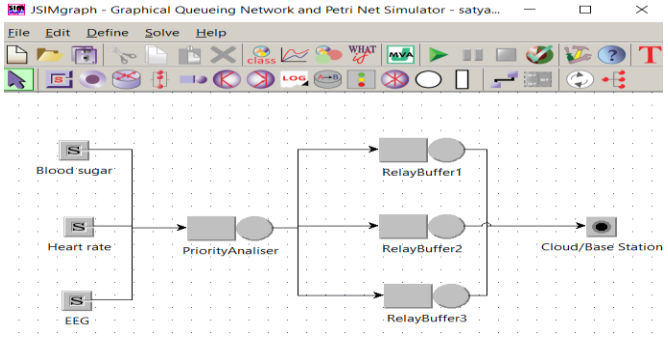

Figure 2. Simulation Setup

IV. RESULT ANALYSIS

In this section the performance matrices are presented in the terms of simulation graphs. The traffic arrival is taken from heart rate sensor for analysis of the performance factor in this simulation study as it is consider to one of life saving parameter for real time analysis and required immediate prioritised transmission. Performance curves for the proposed models- Response Time, Throughput, Drop Rate, Utilization and Queue Time are plotted in the below figures.

In Figure.3 the performance of Drop rate of Heart Rate data with respect to the arrival time (Heart Rate data) is presented. Here we have considered the Drop Rate as PA. It can be observed that the Drop Rate of Heart Rate data increased sharply with arrival time. But the Drop rate of Blood Sugar and EEG data remains constant. This is due to arrival of priority based Heart Rate data that suppresses Blood Sugar and ECG data transmission. Hence the model shows effect of priority data in WBAN with better performance.

The effect of Queue Time (QT) at each relay node with arrival of Heart Rate data is shown in Figure.4 . We can observe that with increase of arrival rate the queue time increases at every relay buffer. But relay buffer3 shows the minimum queue time for the arriving Heart Rate data as it possesses non-pre-emptive scheduling (priority). Hence relay buffer3 out performs by providing quick service to prioritise Heart Rate data.

Figure.5 illustrates the System Response Time with respect to arrival time of Heart Rate data. It can be seen that response time varies with increase of arrival rate but does not create constant pattern. On the other hand due to prioritised nature of Heart Rate data it shows minimum response time to get served and out performs.

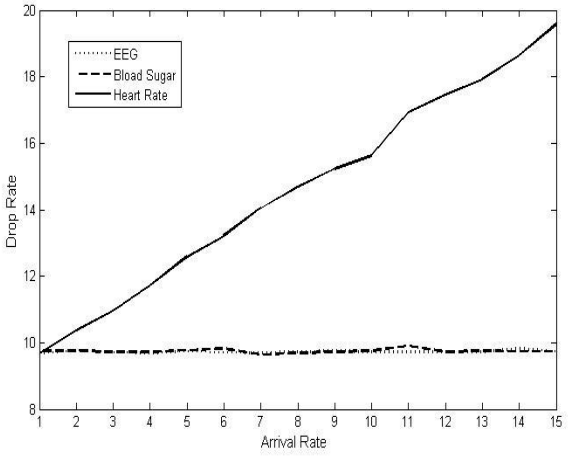

Figure 3. Drop Rate Vs. Arrival Time

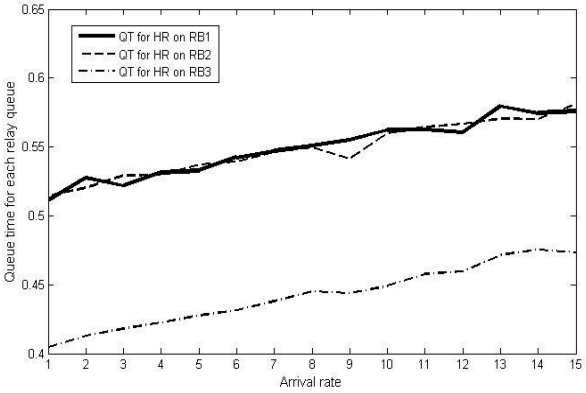

Figure 4. Queue Time Vs. Arrival Time

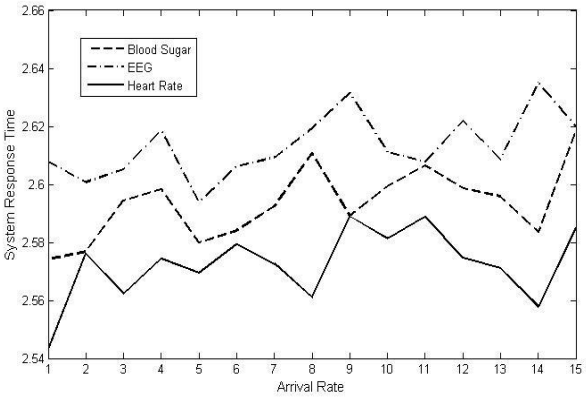

Figure 5. System Response Time Vs. Arrival Time

The System Throughput behavior with increasing arrival time of Heart Rate data for different service rate at PA is presented in Figure.6. For any of the service rate, throughput increases with arrival time. But when service rate of Heart Rate data is 1.5 throughputs becomes maximum i.e. priority based Heart Rate data is served with high throughput. Hence high service rate shows better throughput.

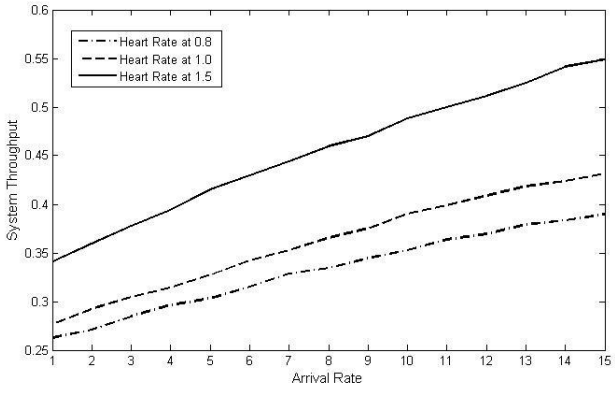

Figure 6. System Throughput Vs. Arrival Time

In Figure.7 we have study the Utilization of PA for different sensor data with respect to arrival rate of Heart Rate data. It

is found that with increase of arrival rate utilization of PA for Heart Rate data increases sharply whereas utilization for Blood Sugar and EEG decreases. As Heart Rate carries the high priority stamp it is allowed to get served earlier than Blood Sugar and EEG that increases the utilization.

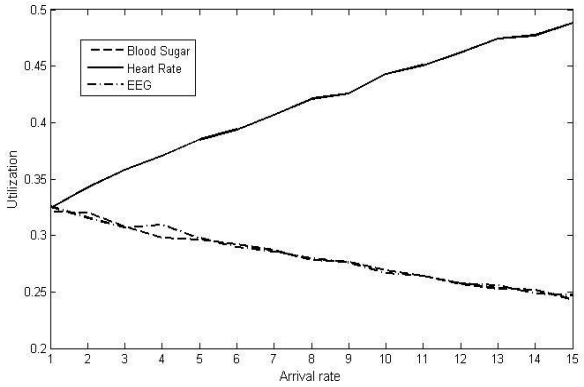

Figure 7. Utilization Vs. Arrival Time

V. CONCLUSION

In this paper an overview of Wireless Body Area Network (WBAN) and its working framework is provided. Also the buffer-aided multi relay WBAN system is studied and the drawbacks are presented. But transmission of vital body parameters with priority as per the patient's health does not presented in any literature.. Hence we proposed a modified framework for buffer-aided multi relay WBAN with priority setup. The model is simulated using JMT and the results are illustrated for throughput, utilization, response time and drop rate in terms of graphs. The priority data (HR) transmitted faster than the other body parameter (BS and EEG). Though we have used a fixed priority level but dynamic assignment of priority level is opened as future scope of work.

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