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A class based QoS model for Wireless Body Area Sensor Networks

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Abstract

Wireless Body Area Sensor Networks (WBASNs) applications have emerged as major type of Wireless Sensor Networks (WSN). Ample research work has already carried out to improve the QoS in WSN. However, QoS provision in WBASN needs further investigation. Majority of the research work in WBASN improves the QoS considering timeliness, latency or energy as a basic requirement. Most of the researchers working on MAC layer consider one of the QoS parameter energy, timeliness or reliability. This paper proposes a class based QoS model for QoS support in WBASN.The proposed model simultaneously ensure high throughput and low data latency. Our proposed model works on multihop topology. The model provides QoS provisioning by defining three classes of services (i.e. guaranteed service, real time service, and best effort services). Data categorized into three classes and scheduled according to their priority with the help of classifier. The schedules data put in the queue and then served from here according to their priority. We highlighted the need of QoS support in BASN by evaluating the performance of BASN by using Castalia when there is no QoS provision in various scenarios. The proposed QoS model support for high throughput and low delay for critical data. In WBASN critical data needs to be delivered quickly particularly in medical applications. Our proposed QoS model increases the critical traffic throughput by ensuring a minimum delay of the critical nodes. We implement the proposed model through simulations and the results show that the proposed model improves the delay and throughput of the critical nodes.

Keywords: Quality of service, wireless body area sensor networks, wireless sensor networks.

Introduction

In recent years, Wireless body area sensor networks have been receiving the more attention in academic and industry areas. The researchers, system designers, and application developers have shown a great interest in the development of this new type of network architecture due to the availability of much less expensive sensors with computation and communication capabilities.

Body Area Sensor Network (BASN) is a network, which comprises of a set of mobile and compact sensors, communicates with each other; these sensors are either wearable or implanted in the human body that continuously monitored vital body parameters and movements. BASN is imagine to release a system that introduces something that personalizes, and combines the life style and behavior of a person, which includes fitness, entertainment and way of consuming electronic applications. BASN can enable a wireless connectivity, implanted cardioverter defibrillators (ICDs), implanted drug delivery, swallowed camera pills, wearable ECG/EMG/EEG/BP/SpO2/temp monitoring, high risk pregnancy monitoring, sleep analysis, gait analysis, emotion detection, media players, and headsets.

WBASN has attracted the researcher time due to the development of small and cost effective wearable sensor devices. Abundant works are going on in this direction, along with open issues like standardization, energy efficiency; security and privacy factors. QoS issue is also of major concern. QoS refers to an assurance to provide a set of measurable service attribute to the end-to-end users/applications in terms of parameters such as delay, jitter, available bandwidth, and packet loss. The goal of a network is to provide the QoS services while maximizing network resource utilization.

Numerous routing protocols have been proposed for the traditional networks[1-3]. However; these routing protocols cannot be employed on the WBASN system due to their different nature of applications environment. Despite a lot of work have done in the advancement of wireless technology, QoS in WBASN is still a complex job. In traditional network, main QoS parameters are through put, delay, jitter and loss error rate. Data criticality and condition dependent come as additional parameters in WBASN. Packet error rate, latency and energy consumption per packet can be highly problematic in WBASN. Although WBASN inherits all the QoS requirements from the traditional networks but the direct implementation of QoS provisioning schemes does not fit well in WBASN. The requirement of data criticality and condition dependent for the QoS in WBASN demands a new QoS solution in WBASN.

Due to heterogeneous working requirement, WBASN defines different QoS issues, which are specific to that particular application only. QoS requirements may vary based on context. WBASN applications are very sensitive hence require more attention and focus on QoS issues. However, QoS issues in sensor networks did not get lots of attention as compared to other aspects such as architecture and protocol design, energy conservation, security[4-6], location and positioning of nodes.

Related Work

QoS aware routing in WSN divided into two classes Integrated and Differentiated. The integrated services involve the prior reservation of resources before sending it onto the network while no prior reservation is required in differentiated services. In differentiated services, you just mark the packets and send it onto the network. The QoS in WBASN is varying from application to applications. Two QoS differentiation schemes have been proposed for the IEEE 802.15.4 CSMA-CA to support differentiated latency and reliability requirements[7]. It uses different strategies to adjust back off window size to prioritized different types of nodes in latency differentiation scheme. In the reliability differentiation scheme (RDS), more transmission opportunities give to the nodes, which have strict reliability requirement. Results show that prioritized nodes achieve significantly less latency and higher packet success rate than normal nodes. The performance of WBASN (wireless body area sensor network) is often decrease in ambulatory condition due to body obstruction or radio interferences from environment. The performance of BAN (body area network) are often decrease in ambulatory condition due to body obstruction or radio interferences from environment.Multi-stage low complexity QoS layer is proposed suitable for ambulatory conditions which consists of a set of linked lists interconnected in such a way that different types of defined services (data consistency, latency, node lifetime and memory) could be guaranteed[8].

Some researchers have suggested QoS at MAC layer[9,10]. Khaled A. Ali et al. [9] proposed, an urgency based MAC (U- MAC) protocol which is based on the IEEE 802.15.4a standard at 2.4 GHz. In U-MAC protocol, slotted Aloha access mechanism used in which sensor nodes contend for the medium only at the beginning of each time slot of the MAC frame. At the beginning of each time slot, the network traffic divided into two broad categories critical and non-critical. Critical node transmission prioritized over non-critical node transmission by cutting-off retransmission node packet. The protocol has evaluated mathematically. The results show that the number of critical nodes and their packets arrival rate decreases as the number of packet retransmission of such nodes is increased.

Gang Zhou et al.[10] presents the design and implementation of QoS system for body sensor networks, called Body QoS. It addresses the three unique challenges (asymmetric architecture, virtual MAC and adaptive resource scheduling strategy) to provide statistical bandwidth and reliable data communication in WBASN. Guowei Wu et al.[11], proposed a decentralized inter-user interference suppression algorithm for WBASN, namely DISG.

WBASN deals with the variety of health care services. Due to its critical and real time nature delay is the key feature of the WBASN.WBASN is gaining popularity due to its large scale of applications in eHealth. Mrinmoy Barua et.al,[12] propose a packet scheduling schemes for real time transmission in WBAN. This proposed method is designed considering security and privacy e-health application.

To improve the QoS for the IEEE 802.15.4 based Wireless Body Sensor Networks (WBSN) a novel mechanism is proposed by keeping the backward compatibility[13] . It has been seen that the performance of IEEE 802.15.4 can be considerably improved in terms of delay and reliability for inter node and intra node communication while keeping the backward compatibility to ensure interoperability. It also improve establish the differentiation among the nodes within the network. The proposed mechanism validated and implemented on the AcquisGrain WBSN platform.

Prolonging network lifetime is a critical issue in WBASN, so energy constrained sensor nodes must carefully optimized. A novel QoS cross layer-scheduling mechanism is proposed to optimize the MAC layer performance in terms of QoS and energy consumption into the Distributor Queuing Body Area Networks (DQBAN)[14].

Research Challenges

From the literature discussed above, we note that the QoS in WBASN is provided into two classes i.e., class A and class B based on the critical and non-critical sensor. Critical sensor ensures a minimum latency. The QoS in WBASN depends on three parameters; packet error rate, latency and energy. From the above-mentioned review, we had seen that most of the work has done on the MAC layer some also done work on the network layer.

Most of the researcher working on MAC layer considering one of the QoS either on energy, timeliness or reliability few of them can simultaneously satisfy all the three desirable properties such as energy, timeliness and reliability. We propose a model for QoS support in WBASN considering various application of BASN.The proposed model provides a low delay and high throughput for the critical sensor node.

Our proposed model provides QoS provisioning in three classes: class A for guaranteed service, class B for real time service and class C for best effort service. We will divide the data traffic into three categories with the help of classifiers and put it into three different priority weighted queue. We will initially test the model using the existing routing protocols in WBASN.

Class Based QoS Model

Network Architecture: Our proposed technique is based on the following assumption that biomedical sensors are placed on different parts of the body for sensing the important measure such as temperature, blood pressure etc. These sensors nodes, which placed on the body, collect physical data and are capable of performing some computation, storing small amount of data and forming network wirelessly so that they can transmit the sensed data to the sink node. The sink node assumed to have more processing power, battery and data storage capacity. It is the responsibility of the sink node to collect and transmit data towards the base station in order to share over the internet as shown in figure-1.

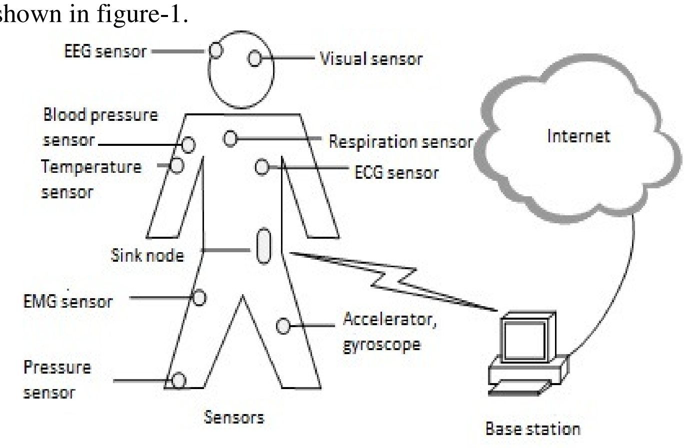

Figure-1
Architecture of Body Area Sensor Network

Functionality of the proposed Class Based QoS Model: The QoS is required when different nature of applications competes for the resources. The QoS in WBASN depends on three parameters: packet error rate, latency and consumed energy. Most of the researcher are working on MAC layer considering one of the QoS parameter energy, timeliness or reliability; very few of them can work simultaneously satisfy all three desirable properties such as energy, timeliness and reliability. The sensors in BASN can be divided into either critical or non-critical sensor based on their type, transmission delay requirement.

The proposed class based QoS WBASN model divided into three classes: i. Class A for guaranteed services. ii. Class B for real time service. iii. Class C for best effort services. iv. These three classes based on critical sensor with very minimum delay, non-critical sensor with minimum delay and non-critical sensor with high delay respectively.

We consider the network, which shows in figure-2, where the traffic between sensor and sink divided into three classes. The traffic, which is going, and coming towards the critical sensor with very minimum delay requirement are a part of class A, class B includes a traffic, which routed through non- critical sensors with minimum delay, while the traffic, which moved through the non-critical sensor with high delay requirement, can be considered as a part of class C. For example, in case medical application monitoring ECG, EEG of the patients will fall in the class A. In another example, the video transmission sensor is included in class B, the objective of these category sensors is to provide real-time monitoring; the rest of the applications fall in category C where the transmission delay requirement is high.

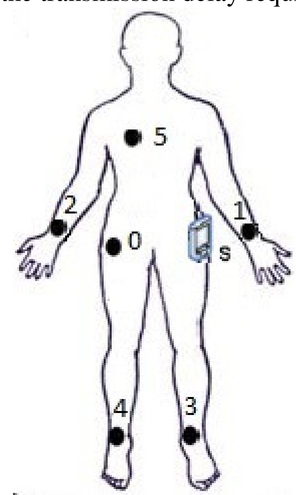

Figure-2
WBASN with sensor model

The above classes can implement together or individual based on application or the scenario requirement. This model tries to assure providing good quality of service for the reliable and guaranteed transmission between wireless sensors by keeping the following constraints i.e. latency and energy. Due to different implications of application in the WBASN, it is difficult to provide continuous reliable real-time data transmission, in some cases delay is unbearable like in monitoring of heartbeat of the patient and some of the applications need longer network life to provide uninterrupted services so they need energy efficient protocol.

Each node maintains the information of class and priority queue. The information of classes maintain, when the data packet sent by node to the network layer. We add two bits inside the header of the flag to define the class of data with respect to the type of sensor. With the help of these two bits, we can distinguish between the data of different classes, i.e. Flag value (01) represents the data of Class A, Flag value (10) represents the data of Class B, Flag value (11) represents the data of Class C.

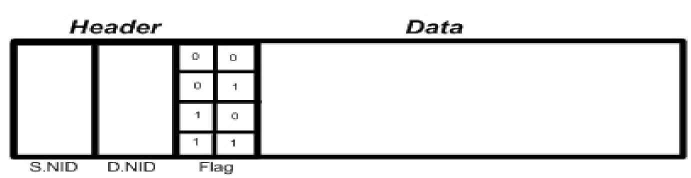

Figure-3
Format of Data Packets with flag bits

Figure-3 shows the simple architecture of the data packets, which consist of two main parts Header and Data. The header of the packet further divided into three parts S.NID (source node ID), D.NID (destination node ID) and flag, the flag value define the type of data traffic.

The classifier is used to categories the individual sensor node data into one of the above-mentioned classes. The classifier has a predefined database in which they have the information about the different types of sensor. Each class based on one of the above-mentioned parameters. After receiving a data packet, the classifier first read the value of flag from the header of the packet and then searches it in their own database. If the value matches in the given database then it identifies the class of the packet (i.e. class A, class B or class C) otherwise assign it to the class D. After identifying the class of the packet, the second thing is to set the priority queue value of the packet, which depends on two factors that are sensor priority value and delay tolerance. The packets forward with the defined priority value are en-queue inside the priority queue according to their priority queue value. The scheduled data then given to the existing routing protocols in WBASN to test the model.

System Model: In our system model, we classify the data packets into three classes based on the services they are provided. Class A represents the data packets of guaranteed service with stringent delay, class B for real time service with minimum delay and class C for best effort service with high delay. Figure-4 shows the basic architecture of our proposed class based QoS model. The incoming packets are classifies with the help of classifier into three different classes. The classifier is also set the priority level of the packets based on the sensor priority value and delay tolerance. After identifying the class and the priority level of the packet, the packets are en-queue into priority queue according to their assigned priority level and they are de-queue with the same priority level.

Classifier: A classifier is playing a very important role in our proposed class based QoS model. It contains a database in which it has the information about the class of the packet, type of sensor and delay tolerance. The classifier is doing two very important task as shown in figure-5 , first it identify the class of the packet and second it set the priority level of the packet. It forwards the packet with the defined priority.

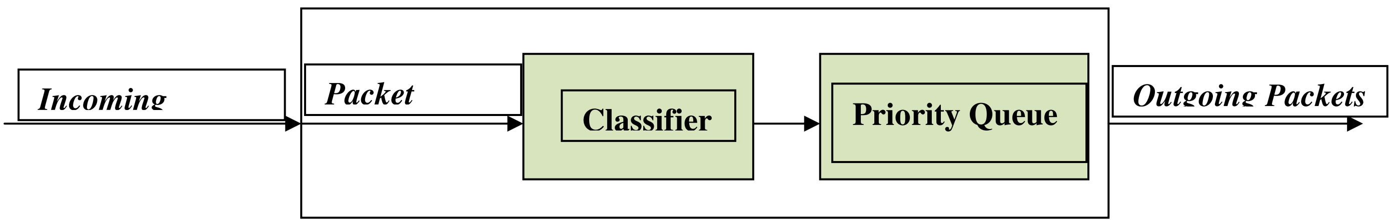

Figure-4
Basic Architecture of Class Based QoS model

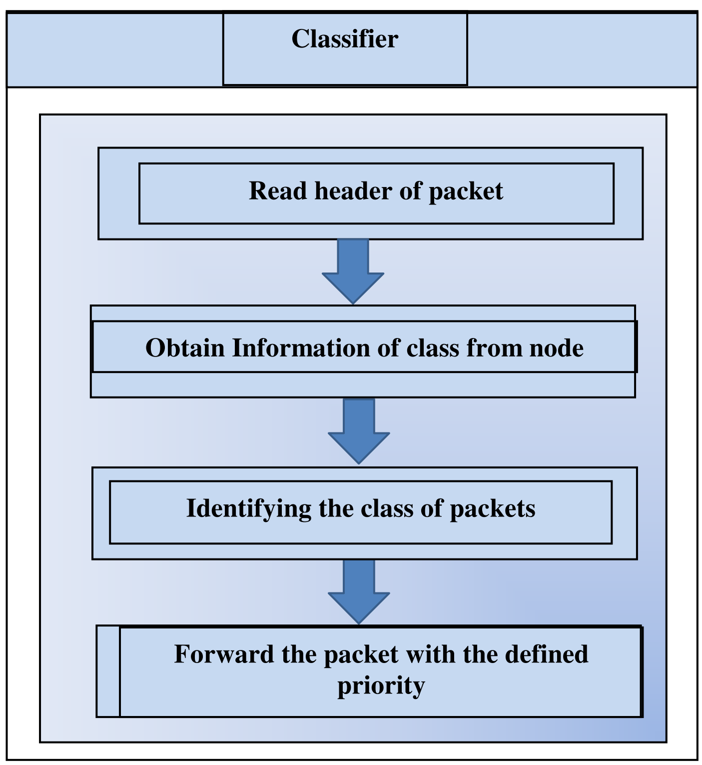

Figure-5
Class Based QoS model Classifier

Identifying the class of packet: The classifier first read the header of the packet; the header contains a two bits flag value, on the basis of flag value it decides that the packet belongs to which type of class. After reading the value of the flag from the header of the packet, it searches it in their own database. If the value of the flag is matched with the database value then assign it to one of the known class i.e. class A, class B and class C, and if the value of the flag does not match inside the database then it assign it to the unknown class i.e. class D.

Identifying the priority level of packet: When classifier identifies the class of the packet, the second important task is to set the priority queue value of the packet. If the delay requirement is small then priority value is high and if the delay requirement is larger than the priority value is smaller. The packets are en-queue and de-queue in the priority queue based on its priority queue value. The priority queue value calculated with the help of sensor priority value and delay tolerance. Priority of the packet determines the degree of importance and the types of data. Generally, the medical applications have the highest precedence over the non-medical applications. The order of data categorized as continuous data, periodic data, and then non-periodic data. The priority classification summarizes in the table-1.

In the initial stage, we set the sensor priority value and range of the delay tolerance in millisecond. We assign the priority sensor value 1 for emergency alarm, 2 for medical continuous,3 for medical routine, 4 for non-medical continuous and 5 for other data types. The delay requirement defines the range of maximum delay tolerance of packet in milliseconds. The priority queue value for the prioritized queue calculated with the help of the following formulas:

$$P = \mathrm{frac}(x) = \begin{cases} x - \lfloor x \rfloor, & x \geq 0 \\ x - \lceil x \rceil, & x < 0 \end{cases} \quad (1)$$

Where $x = PSV - DT$

In the above formula: PSV=Priority Sensor Value, DT=Delay Tolerance.

After calculating the priority queue value, the packets are forward towards the priority queue with their defined priority level.

Priority Queue: The packets are coming in the priority queue according to the calculated priority value. The priority values calculated with the help of equation -1.Packets are en-queue in the priority queue at their exact position. They served from the queue through their position as shown in figure-6. If the priority value is less than 0.4 then the data packet will be en-queue at the last of the queue.

Table-1
Priority Classification

Class	Priority sensor value	Data Types	Examples	Delay Requirement	Range in ms
Class A	1	Emergency Alarm	emergency signs, battery depletion	very minimum	0.1
	2	Medical Continuous	EEG/ECG/EMG	minimum	0.1 - 0.2
	3	Medical Routine	temperature, Blood pressure	minimum	0.1 - 0.3
Class B	4	Non-medical continuous	real time audio ,video	minimum	0.4
Class C	5	others	file transfer	high	0.4 - 0.5

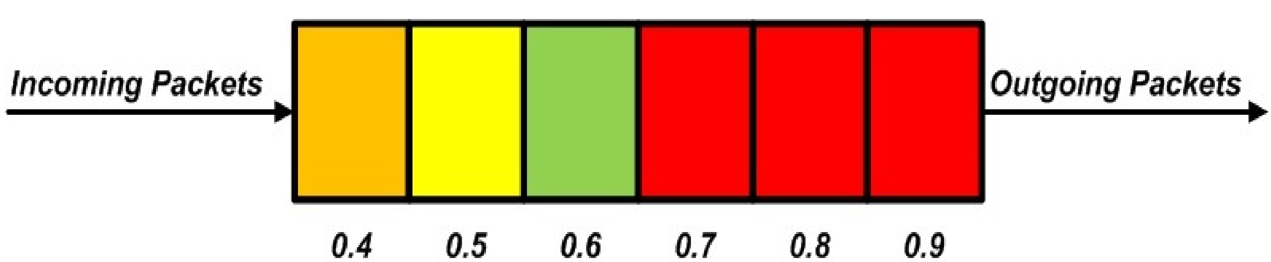

Figure-6
Priority Queue

Estimation Priority Queue: The development of WBASN brings a number of research challenges. Delay and energy consumption is one of them. The life of the network is maximizing by utilizing energy efficiently. To avoid the negative impact of electromagnetic radiation on the human body, it is critical to keep a low transmit power in WBASN. However, the path loss in WBASN is usually larger than 50 dB. Delay means time require to travel a packet from source to destination. In some applications, the delay tolerance is negligible; in these, type of application the information of packet considered useless if the packet should not delivered within the time limit.

Performance Evaluation

No QoS Model: We evaluate the performance of BASN when there is no QoS provision. To evaluate the performance of BASN with no QoS support we simulate two scenarios using Castalia simulator, which used to simulate the low power operational devices.

The first scenario run with the no-provision of QoS and all the six nodes are alive while in the second scenario, we run the simulation having two sensor nodes die due to either consumed power or mobility. The parameters of the simulated environment shown in table-2, the position of the nodes describe in table-3 as visualize in figure-2.

Table-2
Configuration of parameters

Parameter	Value
No. of nodes	6 nodes
Transmit power	-15dB
Simulation time limit	500 sec
Start-up delay	1 sec
Packet rate	5 pkt/sec

Table-3
Position of the nodes

Node	Position
Node # 0	R-hip
Node # 1	L-wrist
Node # 2	R-wrist
Node # 3	L-ankle
Node # 4	R-ankle
Node # 5	chest

In each simulation run, the active nodes randomly selected while the sink node is fixed. In first simulation run, all sensor nodes are active while in second simulation scenario some paths are unavailable as some node become die due to complete use of their energy. We evaluate the impact of two simulation runs on the average end-to-end delay and calculate the total amount of energy consumed for transmission of packets by source nodes until they receive by the sink node.

Figure-7 shows the energy consumption while the figure-8 shows the delay tolerance in two scenarios A and B. The result shows that the average end-to-end delay and energy consumption increased due to the failure of paths in the absence of QoS provision. A slight increase in energy consumption observed in second simulation scenario as depicted from figure-7.

However, end-to-end delivery of packet significantly increased in second simulation scenario, which can observe from figure-8. A little variation seen in case of energy consumption and there is a significant increase in end-to-end delay due to the die of some nodes. Considering these results, we assume that there is a need of QoS model that can improve the performance in terms of energy and delay. We believe that our suggested class based model of QoS will improve the quality of service in terms of consumed energy and transmission delay requirement.

Impact of Class Based QoS Model: We proposed a class QoS model to improve the QoS of wireless body area sensor network. The proposed model improves the delay and throughput of the critical nodes. The proposed QoS model works in two phases. In first phase the sink node broad cast the packets to every node after some interval of time. After receiving the packet from every node sink node extracts the number of nodes present in the network and updates its node table. In second phase on receiving a packet at node classifier reads the flag value from the header of the packet and check it in the database. Assign a class to the packet ac- cording to their flag value. Calculate their priority queue value by using the equation-1. Queue the packet in the priority queue with respect to their priority value and forward the packets according to their priority queue value. Results show a significant improvement in the delay and throughput of the critical nodes after the implementation of our proposed class based QoS model.

Analysis of Path Delay (Latency): The duration taken by the packets to reach the destination is called delay. It is the important matrix to measure the performance of the network. It has been seen that the majority of the data packets reach to the destination nodes with excess delay when the number of nodes increases in real wireless sensor network applications. It is due to the fact that packets need to pass through more nodes before reaching the destination.

Our proposed model works on the network of six nodes that are deployed on the human body. Out of six nodes one is acting as a sink node while the rest of five nodes work as a source node. The source node sent data to the sink by multi-hop routing. In the simulation of 51 seconds each node sends 250 packets to the sink node.

The packet size sent by each node during the simulation is 105 bytes. Moreover, 128K is the size of all packets that are generated during simulation.

We evaluate the performance of BASN when there is no QoS provision and when there is a provision of QoS model. We simulate both scenarios using Castalia. Simulation was performed to measure the efficiency of the proposed QoS model. The first scenario runs with the no-provision of QoS while in the second scenario we run the simulation by applying the QoS model. In each simulation run the nodes are selected randomly while the sink node is fixed. We evaluate the impact of two simulations run on the delay of the critical nodes. Results show that average end- to-end delay is same in both cases. However the individual delay of critical nodes is approximately 33% better, when we applied the QoS model on the nodes. From here we conclude that critical nodes show lower delay as compare to the non-critical nodes in the presence of QoS model. In the absence of QoS model critical nodes show high delay as compared to the non-critical nodes. The individual delay of the critical nodes is increased when there is no provision of QoS model due to the random transmission of packets to the next hop. Improvement in the delay of critical nodes has been seen after the implementation of the proposed QoS model.

Figure-9 shows the delay tolerance when there is no provision of QoS model while figure-10 shows the delay tolerance in the presence of QoS model. A significant increase has been seen in the delay of critical nodes in the presence of QoS model.

Analysis of Throughput of network paths: We evaluate and compare the data throughput by using two scenarios. In first scenarios we run the simulation without the provision of QoS model. Second scenario is run by applying the proposed QoS model. To evaluate the performance we used Castalia simulator.

We take a network of six nodes. Five nodes are sending different types of data to the central node which acts as a sink. Node 1 sending BP; Node 2 EMG, Node 3 temperature, Node 4 gyro and Node 5 sending ECG to the sink. Out of five 2 nodes Node 2 and Node 5 are working as a critical nodes while rest of the nodes act as a non-critical nodes.

The figure-11 and figure-12 show the statistics for throughput for each scenario. By analyzing the above graph we conclude that the overall throughput is same for both the cases. However the maximum throughput values are recorded by the critical nodes in the presence of QoS.

From figure-11 and figure-12 it is also observed that the throughput of the critical nodes is improved approximately 49% after applying the proposed model.

Conclusion

In this paper, we first highlighted the importance of having a QoS provision in BASN applications especially in health care. Then we propose a class based QoS model which provide a low delay and maximum throughput for critical nodes. The classifier on each sensor node used to identify the class of data and prioritized it accordingly. The priority queue transmits the sensory data according to the priority set by classifier. This model is very helpful in the medical applications where the critical data needs to be delivered quickly particularly in the monitoring of chronic diseases. The proposed model data increases the critical traffic throughput by providing a minimum delay. We implemented the proposed model using OMNET++ based Castalia 3.2 simulation environment. The result shows the improvement in terms of delay and throughput of the critical nodes.

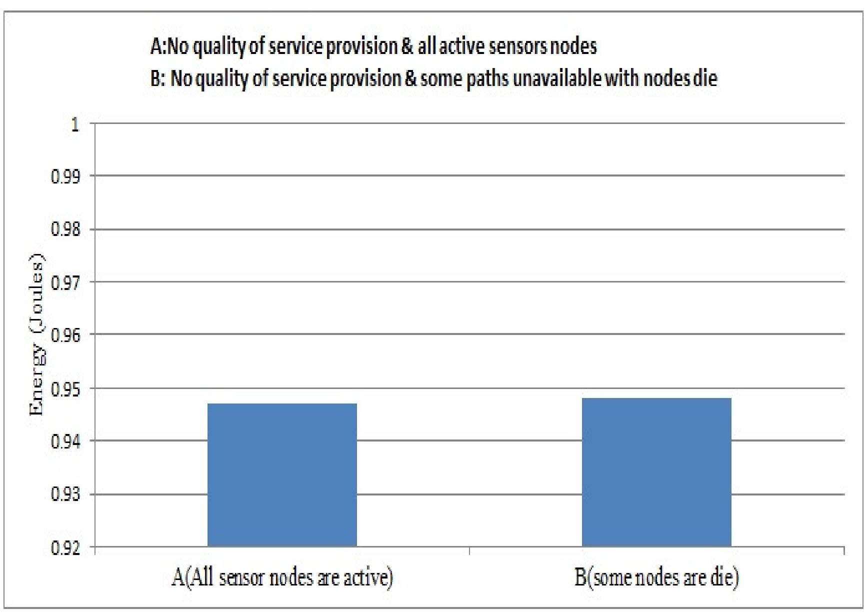

Figure-7
Energy consumption with invalid paths

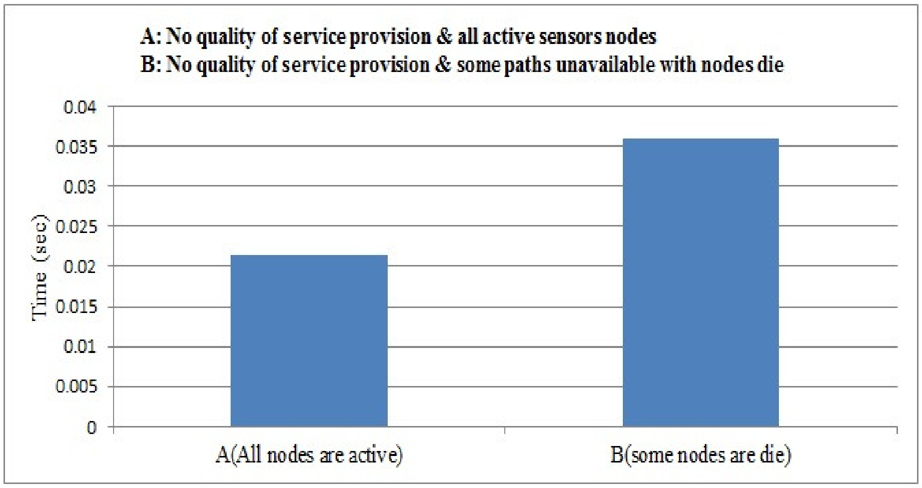

Figure-8
Average end-to-end delay with invalid paths

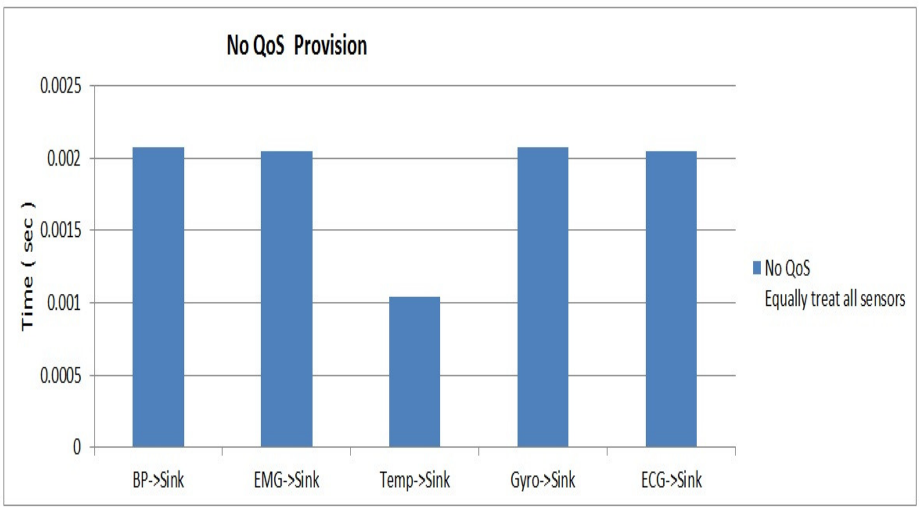

Figure-9
End-to-end delay of paths with No QoS Provision

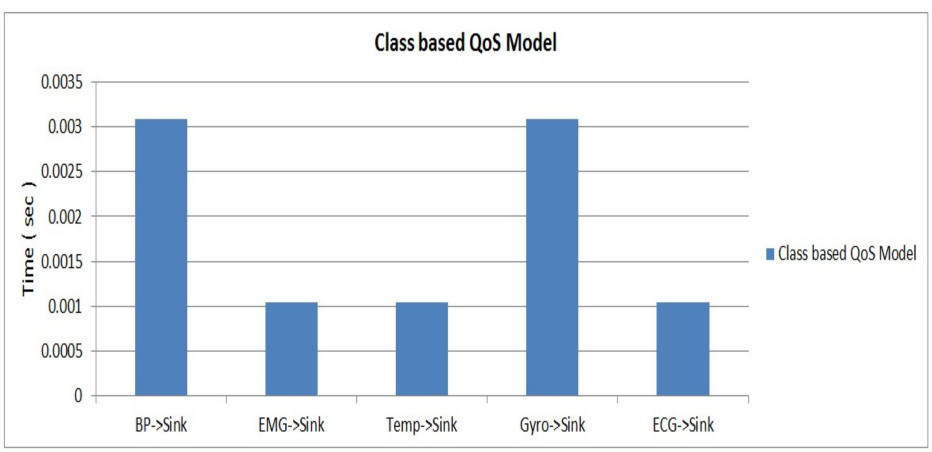

Figure-10
End-to-end delay of paths with class based QoS Model

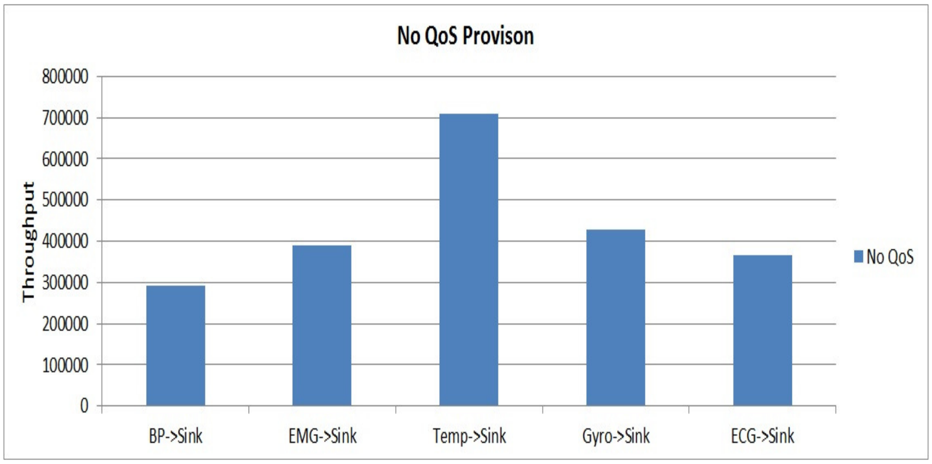

Figure-11
Throughput of different paths with No QoS provision

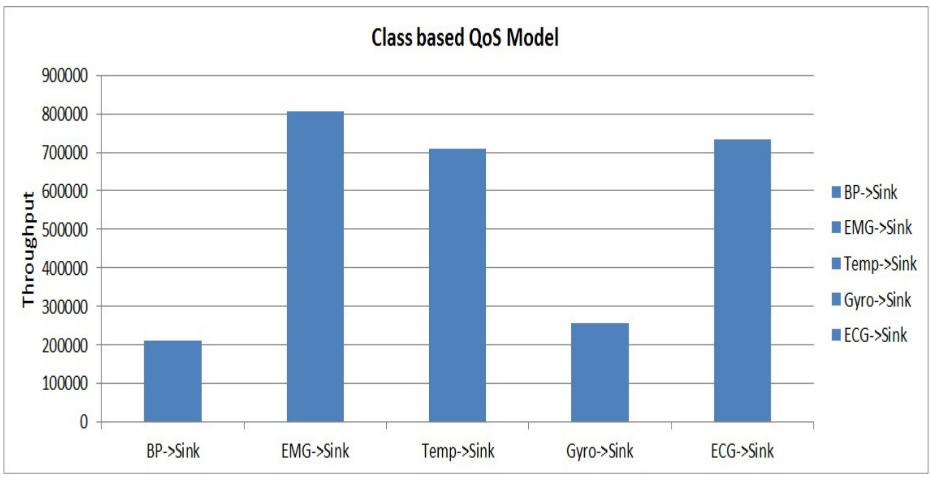

Figure-12
Throughput of different paths with class based QoS Model.

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