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***Research paper***

# An Adaptive Qos Aware Routing with Energy Efficient Approach for Biomedical Wireless Sensor Networks

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**Abstract:**

Biomedical Wireless Sensor Networks (BWSNs) supports the advancement of new health careservices regarding patient monitoring for continuous assessment of patient health and medical diagnosis within affordable cost. On the other hand, dealing with medical data, BWSN should develop mechanisms to provide a high quality of service (QoS) level. As well, BWSN composed with the typical battery powered sensor nodes and these additional QoS mechanisms make extra energy consumption that significantly reduces the lifetime of the network. The network lifetimeis consequently significant feature to assure the needs of QoS.Since, to enhance the network lifetime and its capacity to provide the required QoS new schemes are essential for BWSN.Thus, in this paper, an adaptive QoS aware routing with energy efficient (AQSREE) approach has been proposed for BWMS to assure the QoS of various packets at the same time it minimize the energy consumption of the nodes thus prolonging the lifetime of the network. The proposed AQSREE differentiates the ordinary packets and emergency packet before transmitting in each queue of the node and also selects the optimal route to reach the sink node by considering the packet transmission time, energy level and the link load fulfill the QoS requirements. Additionally, the AQSREE adjusts the contention window size adeptly for energy efficiency with respect to the data rate and energy level. The simulation results show that the proposed AQSREE approach can effectively reduce the energy consumption by ensuring the QoS requirements of BWSN.

***Keywords:*** *BWSN, QoS, energy efficiency, AQSREE, window size adjustment, packet prioritization*

## 1. Introduction

Biomedical Wireless Sensor Network (BWSN) is the combination of wireless network with biomedical sensors that make the advancement in medical scenarios by providing a potential application [1]. The physiological signs such as temperature, blood pressure, SpO2, ECG, heart rate, pulse are sensed by the biomedical sensors that are implanted on the patient body and the sensed data has been transmitted to health center [2], in which the sensed data has been utilized for patient monitoring, health analysis and diagnosis. BWSN allows the mobility characteristics while guarantying that the patients are monitored and cared of continuously.

The main objective of the BWSN is needs to assure that the sensed packet has been delivered successfully and efficiently to the health center. Hence, the routing protocol plays a significant role in the BWS to transmit the data successfully. The routing protocol faces some severe constraints such as Quality of Service (QoS), power supply, communication bandwidth due to the dynamic topology characteristics of BWSN.The requirements of QoSconsidered as one of the important factor that the requirements are different for various users, as the real time medical data which is in high risk must be transmitted with in certain end- to end delay. Whereas other users that has normal data or low risk data may be compromise on certain real-time necessities to enhance the network lifetime, hence low power consumption is their desired QoS needs. Moreover, the routing protocol should select the route that assures the essential bandwidth requirement for some high data rate bio sensors such as EEG. Moreover, the QoS awareness should not only concentrate on the typical communication metrics such as packet delivery rate, delay, bandwidth to fulfill the QoS requirements. As the bio sensor nodes are powered with limited power supply batteries and in particular because of the limited power of the batteries, the QoS scheme must be designed correspondingly [3][4]. Hence to minimize the energy consumption of nodes, it is essential to present the energy efficiency so as to enhance the network lifetime.

Thus, this paper jointly optimizes the energy consumption and QoS by proposing an adaptive QoS aware routing with energy efficient (AQSREE) approach for BWSN.The proposed AQSREE differentiates the ordinary packets and emergency packet before transmitting in each queue of the node and also selects the optimal route to reach the sink node by considering the packet transmission time, energy level and the link reliability of the path to fulfill the QoS requirements. Additionally, the AQSREE adjusts the contention window size adeptly for energy efficiency with respect to the data rate and energy level.

The rest of the paper is organized as follows: Section 2 presents the recent related works done on QoS assurance and energy efficiency for BWSN. The proposed method has been described in section 3. The experimental and its results have been discussed in section 4. Finally, the section 5 renders the conclusion.

## 2. Related Work

In [1], the author proposed a RL-QRP protocol for BWSN based on reinforcement learning algorithm. With the learning algorithm it determines the feasible routing policies using the experience and rewards in terms of QoS. In [5], the author proposed a protocol namely ZEQoS for body area network to assure the QoS. This protocol focused on two stacks such as Network and MAC layer and designed two algorithms for constructing the neighbor and routing table and one algorithm to select the path. First the scheme prioritize the packet in a manner of reliability-sensitive packets (RSPs), delay sensitive packet (DSPs) and ordinary packets (OPs). Afterwards the designed protocol selects the optimal routes for those packets by accounting their QoS needs.

The same authors proposed QoS-aware routing protocol (QPRD) [6] in 2015 by performing a mathematical analyses in terms of throughput and delay. This scheme enables to compute the node and path delays of all the available routes between two pairs of nodes. Based on the delay requirements, the forwarding nodes have been chosen.

In [7], the author proposed an effective forwarding node selection algorithm for Body area network to assure the QoS with optimal energy consumption. It considers the multi hop environment and selects the route based on the link cost and hop count. The link cost estimation comprises of free buffer size, residual energy and the link reliability.

A network management system with the awareness of QoS has been proposed [8] to make a centralized management environment in order to monitor the patient with the required QoS. This system consists of two modules such as QoS monitoring and admission control module. The QoS degradation has been monitored in the QoS monitoring module to notice QoS degradation events beforehand of the metric get to critical value. The noticed information will be informed to the network manager regarding the effects of those events. Whereas the admission control module admits the new sensor nodes i.e. the new patients by verifying with the virtual sensor nodes.

In [9], the author addressed the deficiency of QOS in the previous MAC protocols and proposed a QoS profile namely DRT that involves the delay, reliability and throughput. The better reliability has been attained with in certain time periods and data rates with the DRT profiles. In [10], the author proposed inters user interference reduction scheme based on game theoretic approach for Body sensor network and the scheme performed without any centralized administration. The game has been modeled to select the channel and transmission power between the players i.e. the node with their interference level as utility.

## 3. Network Model

Let consider that several biomedical sensors such as EEG, ECG, SPO2, Glucose, blood pressure, heart rate has been implanted to a patient. And the acquired sensed data has been sent to the central node which will aggregate and responsible for data transmission and it has been shown in figure 1. The network also contains few relay nodes that has been placed in a static position and it is also assumed that initial energy is higher than the sensor nodes and also enabled with battery replacement. Each patient is considered as a sensor node and transmits their data in a multi hop manner to reach the sink node that store entire details of every patient with the help of some relay node placement.

### 3.1 Packet Categorization

The packets have been categorized into three classes of data packets such as Ordinary Packet (OP), Reliability driven packet (RP) and Emergency Packet (EP). The emergency packets are provided with highest priority, eg., EEG and ECG reading has been monitored for the patients who underwent for the surgery. The Reliability driven packet is the next higher priority packet that should be transmitted without data loss such as PH-level monitoring, respiration monitoring. The ordinary packet is the lowest priority packet that is to be a regular reading of physiological parameters of patient like heart beat and temperature.

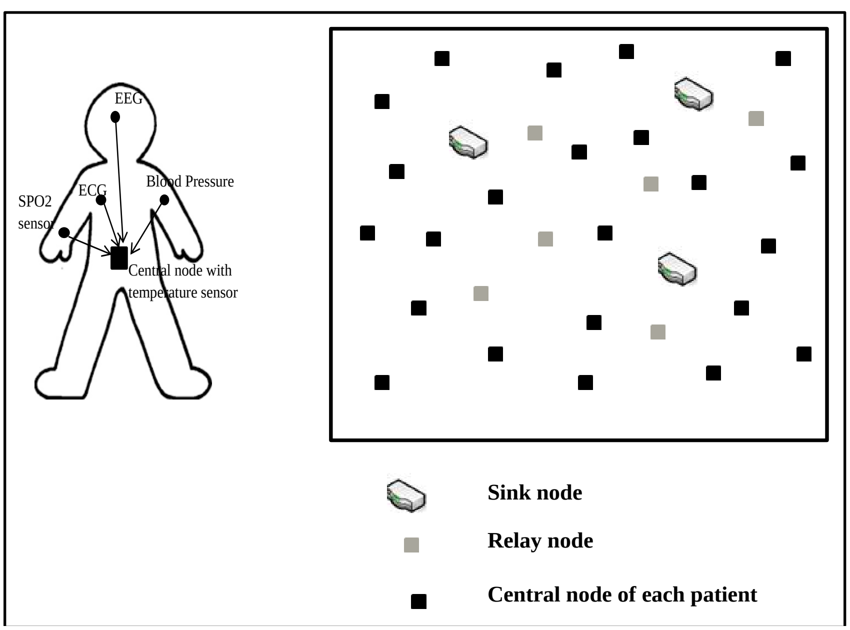


**Figure** 1: a) Patient implanted with bio sensors b)Architecture of BWSN

### 3.2 QoS Aware Routing

The neighbor information exchange is enabled by Hello packet within 1-hop neighboring sensor nodes. The Hello packet will contains the information about the packet transmission time, link load level, energy level and the link reliability and it has been exchanged when the node identifies any of the metrics is in a critical situation.

***Transmission Delay:*** The node measures its packet transmission time in the MAC layer with the weighted average transmission delay technique. Transmission delay will be due to retransmission, channel sensing, backoff time slots. For every packet, the instantaneous delay has been measured which is the time taken for a packet from its ready position of transmission (that it is in the head of the queue) to the last bit of packet reaches the destination node and it has been given in the following equation

$$TD = \frac{\sum_{n=1}^{P} TD(n) \times w_n}{\sum_{n=1}^{P} w_n} \quad (1)$$

Here $w_n$ is the weight of each packet and based on the number of Packet P the weights has been determined

$$w_n = 1 - \frac{n-P/2}{P/2+1}, P/2 < n \leq P \quad (2)$$

***Link Load***

The level of the link load LL [11] has been measured by means of load transmission capacity at the MAC layer

$$LL(i,j) = \frac{Q_{ij}}{t_{ri} - \sum_{k \in N_i} tr_{ik}} . ETX_{ij}. \quad (3)$$

Here $Q_{ij}$ indicates the total amount of data transmitted from node i and node j, $t_r$ indicates the bit transmission rate of node i. $tr_{ik}$ indicates an existent transmission rate after connected with node i. $ETX_i$ is the expected transmission times between the node i and node j. $N_i$ is the set of neighbor nodes. While $\sum_{k \in N_i} tr_{ik}$ is going larger and the links are overloaded, then it will leads to congestion.

***Residual Energy***

The residual energy *RE of* each node can be measured by getting the difference between initial energy *IE* and the energy consumed during the transmission and reception and the equation follows

$$RE = IE - (E_{TX} + E_{RX}) \quad (4)$$

The node creates l-bit of packets and disseminates the packet over a distance d. The first order radio model can be used to measure the transmission energy consumption and it is given as follows

$$E_{TX} = \begin{cases} l.E_e + l.E_{fs}.d^n & d < d_0 \\ l.E_e + l.E_{mp}.d^n & d > d_0 \end{cases} \quad (5)$$

Where, $E_e$ is the energy consumption by means of electronic circuitry (transmitter or receiver), $E_{mp}$, $E_{fs}$ is the amplification loss of power in the free space and multipath fading channel, $d^l$ is the transmission distance (l=2 for free space, while l=4 for multipath fading channel model) and $d_0$ is the threshold limit and it can be given as follows

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (6)$$

The energy dissipated during the time of data reception of l bits and it given as follows

$$E_{RX} = l.E_e \quad (7)$$

The AODV routing has been used as the underlying protocol for this approach, where the route is discovered on the on-demand basis. When a node i desires to transmit the data and AODV protocol broadcast the RREQ packet to the nodes which are in the safe state (i.e) by considering the QoS metrics used in this approach. Based on the priority of the packet, the node selection will be different for selecting the node as a forwarding node. The node which contains the huge amount of data to transmit such as EEG and ECG, it will first check the available bandwidth will be enough to transmit the data, and then the RREQ packet will be forwarded to that node. The node which contains low data rate to transmit the data may select the node that has enough energy to transmit the data by computing the transmission energy of those l bits of data and the transmission delay is not a constraint for that prioritized packet i.e. RP and OP. Moreover, the node which contains the EP will contains all the QoS metrics constraints. The OP has only constraints on the energy level due to selecting the node going to dead is invalid. Moreover, the load the next node j is high then the node i can fragment the packet and transmit to the node j.

Step 1: Source node s to transmit the data to the sink node $d_1$
Step 2: For ito n, where n is the number of neighbor nodes
Step 3: if $P \in EP$ then
Step 4: if $TD > TH_{Td} \&\& LD > TH_{LD} \&\& RE < TH_{RE}$
Step 5: Avoid $node_i$ as a forwarding node
Step 6: else
Step 7: Select $node_i$ as forwarding node
Step 8: else if $P \in RP$
Step 9: if $LD > TH_{LD} \&\& RE < TE(l - data\ bits)$
Step 10: Avoid $node_i$ as a forwarding node
Step 11: else
Step 12: Select $node_i$ as forwarding node
Step 13: else if $P \in OP$
Step 14: if $RE < TE(l - data\ bits)$
Step 15: Avoid $node_i$ as a forwarding node
Step 16: else if $(LD > TH_{LD})$
Step 17: Fragments the data packet and selects the $node_i$ as forwarding node

Step 18: else
Step 19: Select $node_i$ as forwarding node
Step 20: end for
Step 21: repeat the step from 2 until the sink node has been reached

**Algorithm** 1: QoS aware forwarding node selection

After the RREQ packet reaches the sink node, the RREP packet will be transmitted in the reverse path towards the source node. The source node can select the node with minimum hop distance.

The Queuing model adopted for this approach is same as the model used in [5], where the starvation problem in the Queue model has been evaded by using the aging technique. After selecting the relay nodes to forward the data packet, the queuing model will be taken place at every node. Each node will contain three types of Queue to separate the data from each other among three classes. Since the EP packet has the higher priority and the queue separated for that packet is loaded all the times to a node then the waiting time of RP and OP packet will be huge due to transmitting the prioritized packet first all the time. This starvation problem has been evaded by considering the time out of the packets and time out of packet is come across certain level, then the packet will be shifted to the high priority queue. In the Route Maintenance phase, the AQSREE approach monitors the congestion level of the link connected between two node I and j by measuring the link load. When the link load is heavy then the node i checks it is tolerable level, if it means then the data fragmentation has been processed at the node I and the fragmented data will be sent to the node j. Otherwise, the link load is not tolerable even for the fragmented data then the next forwarding node has been selected.

### 3.3 Energy Efficient Contention Window Adjustment in IEEE 802.15.4

Since the proper contention window adjustment helps in attaining the energy efficiency by avoiding the congestion and resource wastage [12] [15]. The IEEE 802.15.4 MAC protocol has been adopted widely in the BWSN due to its optimal resource usage and energy efficiency. In this work, it has been assumed that the network functions using a low duty cycle set with an appropriate choice of beacon order and super frame order parameters of the super frame structure. The contending nodes periodically wake ups for their beacon transmission and attempts to transmit their packet during the active period. Hence, even lower load may results in high packet loss due to high collision rate and channel busy at the commencement of active period [13]. So in this section, an attempt is made to adjust the contention window by addressing the link load, transmission delay and number of contending nodes

Initially, the AQSREE randomly chooses an initial value of CW by means of Backoff Exponent (BE) as (8) that is general technique of IEEE 802.15.4 protocol. If it is supposed that there is a transmission blockage in the network [14], AQSREE adaptively increases the contention window based on the throughput, link load and the number of nodes. Moreover, if it is a low traffic then the congestion window shrinks adaptively

$$CW = Rand(0, 2^{BE} - 1) \tag{8}$$

$$Adaptive_{CW} = CW + \frac{P_{RNG}}{No\ of\ hops}, LL_{Th} < LL || TD_{TH} < TD \tag{9}$$

$$Adaptive_{CW} = CW - \frac{P_{RNG}}{No\ of\ hops}, LL_{Th} > LL || TD_{TH} > TD \tag{10}$$

$$1 < P_{RNG} < CW \tag{11}$$

Here the number of hops indicates the number of nodes to the sink node. $P_{RNG}$ indicates the parameter of CW range. The $P_{RNG}$ can be changed based the data rate of the number of nodes to the sink node. During retransmission time, Backoff Exponential Time BE value can be adjusted dynamically by using the equation 12 and 13. While there is a poor channel status then there are more retransmissions, BE raises. Hence with means of BE, AQSREE can changes the CW value dynamically in frame retransmission time.

$$Adaptive_{CW} = CW + \frac{P_{RNG}+BE}{No\ of\ hops}, LL_{Th} < LL || TD_{TH} < TD \tag{12}$$

$$Adaptive_{CW} = CW - \frac{P_{RNG}+BE}{No\ of\ hops}, LL_{Th} > LL || TD_{TH} > TD \tag{13}$$

## 4. Simulation and Results

NS2 tool has been used to test the performance of the proposed approach AQSREE. The simulations are performed by assuming real 40- bed hospital scenario. The distance between the two beds has been set to 3 meters that is the recommended communication range of BWSN. The used simulation parameters and values have been specified in table 1. Each central node transmits their data to the corresponding sink node with the multi hop scenario. Six relay nodes have been used in this simulation. The performance of the proposed approach has been compared with the existing QPRD and RL-QRP.

**Table 1:**. Simulation Parameters

| Parameters | Values |
|---|---|
| Simulation Area | 250 m2 |
| Number of nodes | 47 node (40 sensor node, 3 sink node, 6 relay node) |
| MAC | IEEE 802.15.4 |
| Packet size | 40 bytes |
| Transmission rate | 250kbps |
| Frequencies band | 420MHz,868MHz, 2.4GHz |
| Channel mode | Log shadowing wireless model |
| Evaluation Parameters | Delay, Energy Utilization factor, packet delivery ratio |
| Simulation time | 400sec |

### 4.1 Performance Metrics

**End to End Delay**

The average time spent by a data packet to reach the sink node. It comprises the packet waiting time in a queue, propogation delay and processing delay.

$$Delay= QD + PD+ PGD \tag{14}$$

Here QD is the queuing delay, PD is processing delay, and PGD is the propagation delay.

**Energy Utilization Factor**

Energy Utilization Factor (EUF) is the ratio of overall energy utilized (EU) throughoutthe entire lifetime to the total energy (TE) delivered to the network during deployment.

$$EUF = EU/TE \times 100 \quad (15)$$

**Packet Delivery Ratio**

Packet Delivery ratio (PDR) is the ratio of t number of packet transmission delivered successfully to the sink node to the number of packets originated at the sensor node.

$$PDR = \frac{No\ of\ packets\ transmitted\ successfully}{No\ of\ packets\ generated} \times 100 \quad (17)$$

**4.2 Discussions**

Figure 2 shows the End to End delay with respect to number of transmission performed in the network. From the figure, it can be observed that the end to end delay increases with the increase in the number of transmission in the network. The QPRD incur maximum delay due to the OP and RP packets waiting in the queue for longer duration. While the packet categorization does not performed in the RL-QRP, the delay will be minimum that the QPRD. Even though the proposed AQSREE performs the packet categorization, the delay optimization at the time of node selection and the contention window adaptation, makes it to acquire the minimum delay when compared to the QPRD and RL-QRP

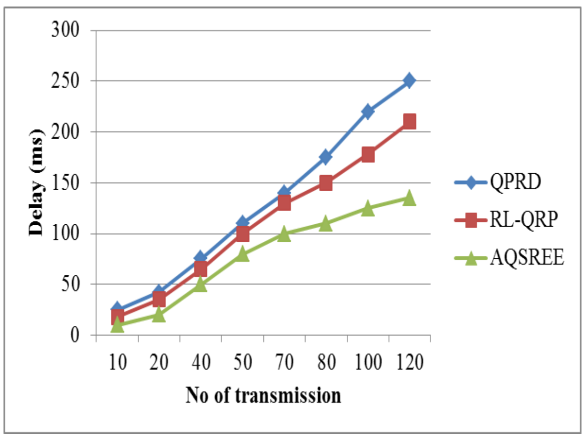


**Figure 2:** Delay with respect to number of transmission undergone in the network

Figure3 shows the packet delivery ratio with respect to number of transmissions performed in the network. The proposed AQSREE selects the optimal data forwarder to transmit the data successfully and moreover by adjusting the contention window and bit rate adaptation, the maximum packet delivery ratio has been attained and it has been observed from the figure 3. For 120 packet data transmission, the proposed AQRSEE attains 96%, while RE-QRP, QPRD attains 86%, 88% respectively

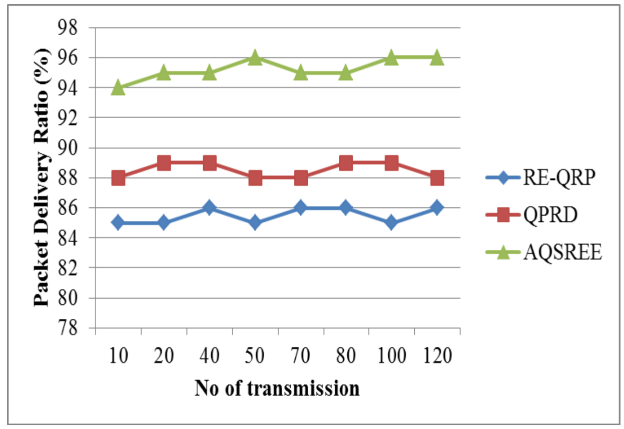


**Figure** 3: Packet Delivery ratiowith respect to number of transmission undergone in the network

Figure 4 shows the Energy Utilization factor with respect to number of data transmissions performed in the network. By considering the residual energy as one of the metric to select the forwarding nodes, the AQSREE avoids the unnecessary retransmission due to selecting the node which could not able to perform that task. Furthermore, it minimizes the forwarding nodes in route discovery which further minimizes the energy utilization. Additionally by selecting the contention window appropriately with respect to the number of hops, link load and transmission delay, energy efficiency has been attained in AQSREE when compared to the existing RL-QRP and QPRD respectively.

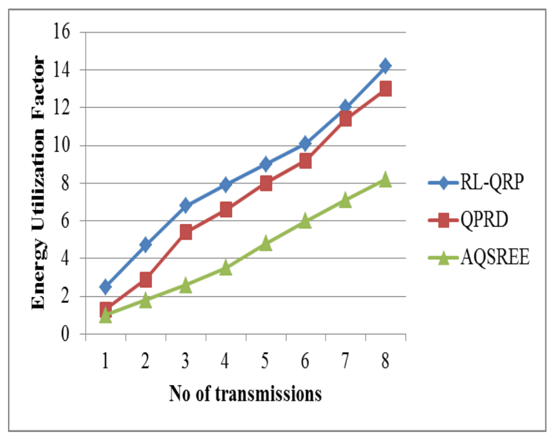


**Figure 4:** Energy Utilization Factor with respect to number of transmissionsundergone in the network

## 5. Conclusion

This paper proposed an adaptive QoS aware routing with energy efficient approach (AQSREE) for Biomedical Wireless sensor network by addressing its shortcomings. Initially, AQSREE categorizes the packet at the source node level itself based on its requirements of QoS. Afterwards, the QoS aware routing has been processed by initially selecting the forwarding nodes based on the packet priorities and then the route maintenance and queuing model has been explained to support the QoS of various patients. Contention Window adjustment has been performed by accounting the link load, transmission delay and number of hops to attain the energy efficiency by avoiding the congestion and excess resource utilization. The simulation has been performed with the real time hospital based environment containing 40 patients and their respective readings of the sensor nodes implanted on their body. The simulation results show that the AQSREE performs better than the RL-QRP, QPRD in terms of packet delivery ratio, end to end delay and energy utilization factor.

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