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Markov Chain Based QoS Support for Wireless Body Area Network Communication in Health Monitoring Services

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Abstract—Wireless Body Area Networks (WBANs) are essential for real-time health monitoring of patients and in diagnosing of many diseases. WBANs comprise many sensors to monitor a large range of ambient conditions. Quality of Service (QoS) is a key challenge in WBAN, because the different state information of the neighboring nodes has to be monitored in an accurate manner. However, energy consumption gets increased while predicting and maintaining the exact information in highly dynamic environments. In order to reduce energy consumption and end to end delay, Markov Chain Based Quality of Service Support (MC-QoSS) method is designed in the health monitoring services of WBAN communication. The energy consumption gets reduced by forming a Markov chain with high energy nodes in the sensor networks communication path. The low energy level sensor nodes are removed using transitional probability in order to reduce end to end delay. High energy nodes are formed in the chain structure of its corresponding path to enhance communication. After choosing the communication path through high energy nodes, the packets are sent to the sink node from the source node with a higher Packet Delivery Ratio. The simulation result shows that MC-QoSS method improves the packet delivery ratio and reduces energy consumption with minimum end to end delay, compared to existing methods.

Keywords—Wireless body area networks, quality of service, Markov chain, health monitoring services.

I. Introduction

WBANs have received tremendous attention in monitoring the health condition of patients. WBANs comprise of sensors capable of monitoring health status of a person. In WBAN, the sensor nodes are smaller in size, lightweight and consume minimum energy. In [1], Delay and Energy Consumption Analysis has been made with different priorities assigned to the body nodes, which are consistent with their data types and sizes. Finite State Markov Model has been used to recognize the node state and guarantee the average delay during normal and emergency data. However, energy consumption does not get reduced. Cooperative Link-Aware and Energy Efficient protocol for WBAN (Co-LAEEBA) has been designed in [2] to learn and select a feasible route which results in reducing the residual energy. However, it does not enable rapid prototyping.

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Integer Linear Programming designed in [3] addresses the high throughput problem and minimizes energy consumption while measuring the physiological parameters. However, the end to end delay is high. QoS aware Framework with Packet Queuing and Scheduling module was introduced in [4]. In [5], a multiple level-based QoS design for WBAN has been presented by Media Access Control Layer by differentiating the data based on the user level, data level and time level and which save the energy with the help of Router Average Priority. QoS architecture in WBAN has been designed in [6]. In [7], Integer Linear Programming Model has been planned with Energy Efficient and Cost Effective WBAN model. Mobile Sensor Monitoring has been presented in [8] through Cross Layer Optimization Platform. The performance analysis of WBANs has been presented in [9]. Taxonomy of QoS for WBAN has been provided in [10]. However, in the above mentioned methods, energy consumption issue remains unaddressed.

The paper initially analyses MC-QoSS method, which is designed for health monitoring services to reduce energy consumption and end to end delay in WBAN. The minimal amount of energy consumption is attained by maintaining Markov chain of high energy nodes on the sensor networks' communication path. The low energy level sensor nodes are removed, using transitional probability so as to reduce the end to end delay. The high energy nodes are collected and formed in the chain structure of its corresponding path of communication. After choosing the communication path, the packets are sent to the sink node from the source using High Packet Delivery Ratio.

Section II of the paper includes the related works. A detailed account of MC-QoSS method is provided in Section III. Section IV presents the experimental setup for conducting the analysis. In Section V, simulation results and a detailed description of packet delivery ratio, energy consumption and end to end delay have been provided. Section VI sums up the paper with its concluding remarks.

II. Related Works

Extensive researches have been carried out in the development of energy efficient protocols using WBANs. An adaptive routing mechanism, used in [11] increases the routing efficiency depending on the quality of the channel link. Nevertheless, the high energy node and low energy node classification has not been carried out in an efficient manner. For improving classification accuracy in [12], Mahalanobis-

Taguchi System (MTS) based classification has been designed. In [13], Bayes Node Energy Polynomial Distribution Model has been planned with minimum communication overhead. To identify the human motion, window-based algorithm was employed in [14] with optimal features. A Distributed Priority Scheduling Strategy has been designed in [15] by ensuring end to end order to prioritize the transmission of patient's present condition.

In [16], QoS aware error recovery mechanism with WBAN requirements, termed as Adaptive Network Coding-based method, has been presented. An analysis of QoS aware health monitoring system was presented in [17]. In [18], a survey of WBAN has been carried out with the latest standards and publications. A distributed algorithm for joint stochastic channel access and rate control optimization was designed in [19] for improving the network throughput for a given energy budget. However, link layer retransmissions remained unsolved. To solve the problem, Orthogonal Frequency Division Multiplexing (OFDM) has been designed in [20] by improving the data rates.

Based on the above issues, presented by the existing methods, in this paper MC-QoSS method is designed for efficient routing in health monitoring services by reducing energy consumption and end to end delay in WBAN. A brief explanation of the presented method is given in the next section.

III. MC-QoSS Method

The deployment of WBAN helps for noticing the patient health. The information is sensed from the patient by utilizing the sensor nodes which are fixed in body. Then, information is transferred in terms of data packets to the sink node. Here, the sink node may be medical server which helps for diagnosing the patient health condition. QoS are handled by WBAN to improve the healthcare.

A. Network Setup

Wireless sensor network '$G = (V, E)$' with vertices 'V' of 'n' sensor nodes is represented as '$V = SN_1, SN_2, \dots, SN_n$'. The set '$E$' of edges denoted as '$E = e_1, e_2, \dots, e_m$' in a sensing rectangular area '$M * N$' with nodes at communication range 'r'. Let 'N_n' is the set of node neighbors and sink node, 'S'. Now, the problem is to design energy efficient routing of the packets from the Source to Sink node which increases the Packet Delivery Ratio and reduces the energy consumption using Markov Chain Model.

B. Markov Chain Model

In MC-QOSS method, energy consumption gets reduced by maintaining the Markov chain of high energy nodes on the sensor network communication path. The Markov chain is formed by choosing the sensor nodes with higher energy. Then after choosing the path, packets are sent to the sink node with minimum end to end delay.

Fig. 1 illustrates the flow processing diagram of Markov Chain Model based on QoS support method. Markov Chain Model not only reduces the energy consumption, but also reduces end to end delay. The energy efficient routing is carried out while sending the packets to the sink node from the source node with better Packet Delivery Ratio.

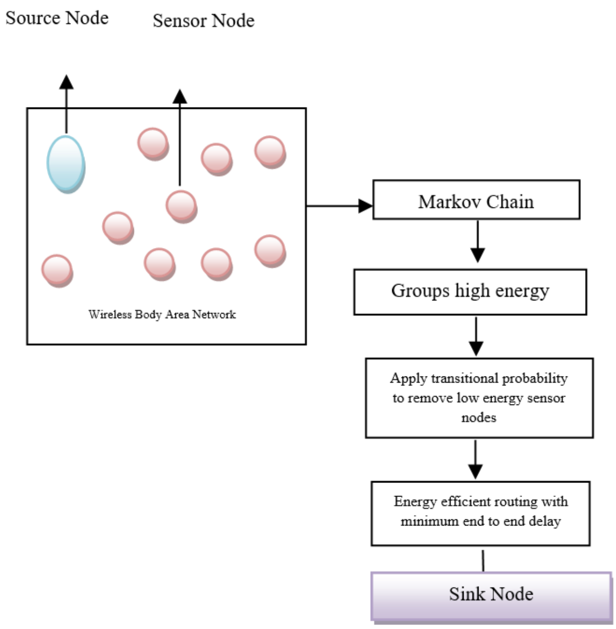

Fig. 1 MC-QoSS Method

The first step in the design of MC-QOSS method is to group the high energy nodes using Markov Chain model. Markov Chain is the process in which changes take place while moving from one state to the other state space. Many nodes in WBAN, using Markov Chain Model are in the transitional process. Markov Chain process forms the chain of high energy nodes to identify the equilibrium distribution. Markov Chain processing is used to predict the next state of the system depending on the present state and not on the previous state. Thus, state transition is performed effectively in the presented MC-QOSS method. The high energy sensor nodes with high energy nodes, are combined to form Markov chain, through which the packets are sent to the sink node from the source node with higher Packet Delivery Ratio.

$$Markovchain = (SN_{i+1} = sn | sn_1 = SN1, sn_2 = SN2 \dots . SN_n = sn_n) \tag{1}$$

The probable chain of the different number of the sensor nodes is denoted as $(SN_1, SN_2, \dots, SN_n)$ in (1). The sensor nodes with high energy level are combined repeatedly. The usage of Equilibrium Distribution Function in MC-QOSS method attains better result, using higher energy nodes by sending the packets to the sink node with higher Packet Delivery Ratio and minimum end to end delay. The equilibrium distribution considers the high energy sensor nodes, which are adjacent to one another. From the result, the higher energy nodes of the distributed sensor nodes are grouped to form a chain using MC-QOSS method with minimal energy consumption.

The Markov chain is in one of the N states for any given time period. Then, the probable entry of P_{ab} explains that the state of the next time is $'b'$ which depends only on the current state $'a'$. It is called as Markov Chain Property. The property of the Markov chain is obtained by,

$$\forall a, b, P_{ab} \in [0,1] \quad (2)$$

With the aid of MC-QOSS methods, the lower energy nodes are removed using transitional probabilities. Each entry P_{ab} is termed as the transitional probability. The transitional probabilities accurately detect the lower energy nodes and reduce the end to end delay. For transition from $'a'$ to $'b'$ in l states, the process is initially carried out from $'a'$ to $'q'$ in $l - x$ state and then transition from $'q'$ to $'b'$ in x states. The l state transitional probabilities $P_{ab}^{(l)}$ is expressed as,

$$P_{ab}^{(l)} = \sum_q P_{aq}^{l-x} P_{bq}^{x} \; x = 0, 1, 2..\text{n} \quad (3)$$

From (3), x is represented as the number of states. The transitional probability with the highest order removes the lower energy node and therefore improves the Packet Delivery Ratio and Reduces the end to end delay. MC-QoSS method is described using the following algorithmic description.

Input: Number of the sensor nodes $SN_1, SN_2, \ldots, SN_n$ **Output:** Minimum energy consumption and High Packet Delivery Ratio
Step 1: Begin **Step 2**: **For** distributed Sensor node $SN_1, SN_2, \ldots, SN_n$ **Step 3**: Evaluate Markov chain process using (1) by forming the chain of the high energy nodes on the sensor network for sending packets to the sink node **Step 4:** Evaluate the transitional probabilities using (3) to remove the lower energy nodes **Step 5:** Route the information to the sink node through the high energy nodes **Step 6**: **End for** **Step 7: End**

Fig. 2 MC-QoSS Algorithm

The above algorithmic description illustrates that an efficient routing is performed by maintaining the Markov chain, using high energy distributed nodes. The transitional probabilities are used to remove the low energy nodes. MC-QoSS method helps to increase the Packet Delivery Ratio with minimum energy consumption and end to end delay, while routing the packet to the sink node from the source node.

IV. Experimental Evaluation

The proposed MC-QoSS method is simulated in the NS2 network simulator 500. Sensor nodes 500 are randomly arranged in an area and each sensor node has similar communication range. The network area is fixed to be 1500 m * 1500 m. Then thickness is continued at a definite level then regularly increased the network size by collective the sensor nodes. In order to maintain the density of the network, once the sensor node increases, the network range also increases. The results of simulation are obtained from several configurations and multiple runs, and the results shown are averaged over 10 simulation runs. Table I illustrates the simulations parameter.

TABLE I
Simulation Setup

Parameters	Values
Network Area 'A'	1500 m * 1500 m
Transmission Range	250 m
Number of Sensor Nodes	50,100,150,200,250,300,350,400,450,500
Number of Data Packets	9, 18, 27, 36, 45, 56, 63, 72, 81, 90
Packet Transmission Time	250 kbps
Mobility Model	Random Way Point
Network Simulator	NS 2.34
Number of Simulation	10
Node Pause Time	0--300 seconds

Dynamic Source Routing (DSR) protocol is used in WBANs with a predefined information. MC-QoSS method is compared with the Existing Priority Guaranteed MAC protocol [1] and Cooperative Link-Aware and Co-LAEEBA [2]. MC-QoSS method conducts experimental works on factors, such as packet delivery ratio, energy consumption rate and end to end delay.

V. Simulation Result and Analysis

In this section, the result analysis of MC-QoSS method is evaluated. The performance of MC-QoSS method is compared with the two exiting methods, namely Priority Guaranteed MAC protocol [1] and Co-LAEEBA [2]. The performance of MC-QoSS method is evaluated along with the following metrics with the help of tables and graphs.

A. Impact of Packet Delivery Ratio

Packet Delivery Ratio 'PDR' is defined as the ratio of the number of packets received successfully at the sink node to the total number of packets sent by the source node. The PDR is obtained as:

$$PDR = \frac{\textit{Number of packets received at the sink node}}{\textit{Total number of packets sent by the source node}} * 100 \quad (4)$$

TABLE II
Tabulation for PDR

Number of Packets Sent (Number)	PDR (%) MC-Qoss Method	Priority Guaranteed MAC Protocol	Co-LAEEBA
9	75	65	52
18	78	67	55
27	81	69	57
36	83	70	61
45	86	72	63
54	89	75	66
63	91	79	69
72	93	81	72
81	94	83	75
90	96	86	78

From (4), the PDR is obtained. The PDR is measured in terms of percentage (%). If the PDR is high, the method is considered to be more efficient.

The result analysis of PDR, using three methods, namely MC-QoSS method, Priority Guaranteed MAC Protocol [1] and Co-LAEEBA [2] is presented in Table II. The MC-QoSS method takes different number of sensor nodes in the range of 50-500 for conducting the experimental works. From the table value, it is proven that the PDR, using MC-QoSS method, is higher when compared to other existing Priority guaranteed MAC Protocol [1] and Co-LAEEBA [2]. Based on the table value, the graph is drawn (Fig. 2).

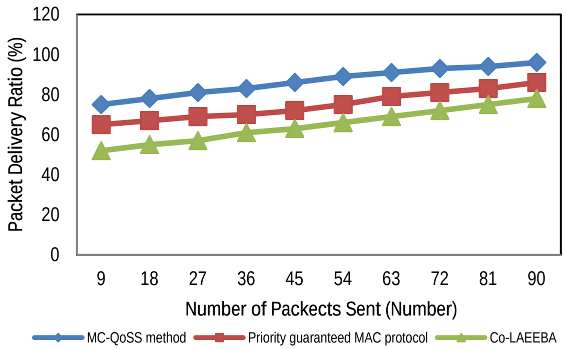

Fig. 2 Measure of PDR

As shown in Fig. 2, the MC-QOSS method gives better PDR than the two other methods, Priority Guaranteed MAC Protocol [1] and Co-LAEEBA [2] respectively for the different number of packets sent. With Markov Chain Model, the higher energy nodes are selected for routing the packets to the sink node from the source node. In addition, the PDR of MC-QOSS method is 13% and 34% higher when compared to Priority guaranteed MAC protocol [1] and Co-LAEEBA [2] respectively.

B. Impact of Energy Consumption

Energy consumption in MC-QoSS method is referred as the amount of the energy consumed for selecting the high energy sensor nodes in the network by forming the Markov chain and by sending the packets to the sink node *'S'* from then source node *'SN'*.

$$Energy\ consumption = EC\ by\ single\ SN * Number\ of\ SN \quad (5)$$

From (5), the energy consumption is calculated by multiplying the energy consumed by a single sensor node $'EC\ by\ single\ SN'$ and a number of sensor node $Number\ of\ SN$ in network. The energy consumption is measured in terms of joule (J). When the energy consumption is minimum, the method is said to be more efficient.

Table III illustrates the energy consumption of three methods, namely MC-QoSS method, Priority guaranteed MAC protocol [1] and Co-LAEEBA [2]. The table shows that the energy consumption of the MC-QoSS method is reduced by using Markov chain process.

TABLE III
TABULATION FOR ENERGY CONSUMPTION

Number of Sensor Nodes (Number)	Energy Consumption (J)		
	MC-Qoss Method	Priority Guaranteed MAC Protocol	Co-LAEEBA
50	198	254	301
100	235	398	452
150	312	424	589
200	457	516	614
250	521	632	732
300	658	752	874
350	723	863	932
400	814	928	1082
450	965	1065	1157
500	1056	1183	1269

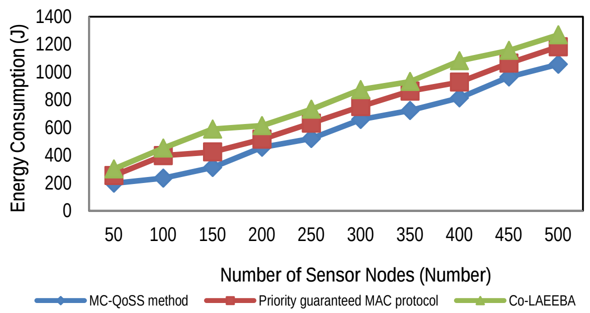

Fig. 3 Measure of Energy Consumption

From Fig. 3, the simulation results of energy consumption are presented for different number of sensor nodes. The Markov Chain is the process in which the higher energy nodes are grouped in the form of chain for effective communication. Markov Chain processing is obtained at the next state of the system depending on the present condition. The transition is performed for maintaining the high energy nodes. By removing the lower energy sensor nodes using transitional probability in WBAN of MC-QOSS method, the energy consumption gets minimized. Therefore, the energy consumption of NLAR technique is 23% and 44% lesser compared to existing Priority guaranteed MAC protocol [1] and Co-LAEEBA [2] respectively.

C. Impact of End to End Delay

End to end delay is defined as the time difference between the sending of packets from source node and receiving of similar packet at sink node.

$$End\ to\ End\ delay\ (ms) = Receiving\ time\ of\ packet - Sending\ time\ of\ packet \quad (6)$$

From (6), $end\ to\ end\ delay$ is measured for different number of packets by source node. The end to end delay is measured in terms of milliseconds (ms). Lesser the end to end delay, more efficient the method is said to be.

Table IV shows the end to end delay in respect to the number of packets ranging from 9 to 90 in the simulation area. When the number of packet gets increased, the delay also gets increased correspondingly. But, the end to end delay of the proposed MC-QoSS method is comparatively less than that of Priority Guaranteed MAC Protocol [1] and Co-LAEEBA [2].

TABLE IV
TABULATION FOR END TO END DELAY

Number of Packets (Number)	End To End Delay (Ms)		
	MC-Qoss Method	Priority Guaranteed MAC Protocol	Co-LAEEBA
9	4.2	5.8	6.8
18	5.3	6.3	7.6
27	6.6	7.5	8.8
36	7.3	8.2	9.7
45	8.5	9.9	10.8
54	9.3	10.9	11.9
63	10.6	11.6	13.8
72	11.2	12.2	14.9
81	12.9	13.6	15.5
90	14.5	15.6	16.9

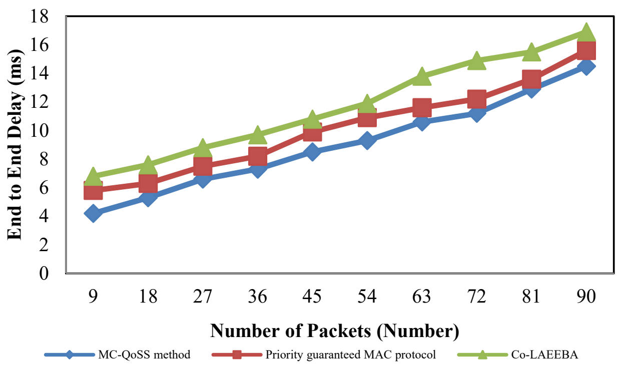

Fig. 4 Measure of End to End Delay

Fig. 4 shows a comparative analysis of the end to end delay in respect to the different number of packets with the existing Priority guaranteed MAC protocol [1] and Co-LAEEBA [2]. The packets, increasing in the range of 9 to 90, are taken for experimental purpose in MC-QOSS method. By using Markov Chain Model, the higher energy nodes are grouped in MC-QOSS method and low energy nodes are removed by using Transition Probability, where the delay gets reduced. The end to end delay is 14 % and 32% lesser in MC-QOSS method compared to existing the Priority Guaranteed MAC protocol [1] and Co-LAEEBA [2].

VI. CONCLUSION

A MC-QoSS method has been designed in health monitoring services by using WBAN communication so as to reduce the energy consumption and end to end delay. Markov Chain Model is used to select the high energy nodes with minimum energy consumption on the sensor network communication path. The low energy level sensor nodes are removed using transitional probability in order to reduce the end to end delay. High energy nodes are formed in the chain structure of its corresponding path of communication with better PDR. The performance of MC-QoSS method is measured in terms of end to end delay, energy consumption and packet deliver ratio while routing the information to sink node in WBAN and compared with Priority guaranteed MAC protocol [1] and Co-LAEEBA [2]. With the simulations conducted for MC-QoSS method, it is observed that the end to end delay gets minimized as compared to the state-of-the-art works. The simulation results show that MC-QoS method provides better performance by reducing energy consumption by 34% and has improved PDR by 24% when compared to the state-of-the-art works.

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