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A Chapman Kolmogorov Hidden Markov with QoS Support for Health Monitoring in WBAN

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Abstract: Wireless body are a networks(WBANs) comprises of sensors capable of monitoring health status of a person. Quality of service (QoS) being a major challenge, due to the link quality of the node, neighboring nodes' different state information has to be monitored in a more precise manner. Despite ensuring energy consumption and delay, difficulty arises while predicting and maintaining this information precisely in highly dynamic environments. This paper proposes an integrated QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) method with the considerations of energy, transmission delay, packet delivery ratio of WBAN communication. The proposed method, called QoS-CKHM, introduces two main modules, Chapman Kolmogorov Hidden Markov and Energy-efficient Medium Access Layer. The Chapman Kolmogorov Hidden Markov module is designed to handle different states in a more precise manner, ensuring packet delivery ratio. The Energy-efficient Medium Access Layer module handle transmission delay sensitive and energy sensitive packets by calculating transmission delay time and allocated time slot for all possible paths from a source to destination, reducing transmission delay and energy consumption. Extensive simulations demonstrate the performance of the QoS-CKHM method. Simulations also show that the QoS-CKHM method offers better performance in terms of higher packet delivery ratio, lower transmission delay and energy consumption than comparable methods including priority guaranteed MAC protocol and iM-SIMPLE.

Key words: Wireless body area networks · Quality of service · Chapman Kolmogorov · Hidden Markov · Medium Access Layer

INTRODUCTION

Recent years have witnessed a significant amount of research interest in WBANs. This is because of their usability and suitable for different range of applications, including both medical and non-medical in nature. With this increasing nature, quality of service has to be rendered to the patients in medical arena. Wide range of studies has been conducted with this regard.

In [1], delay and energy consumption analysis was made with regard to different priorities assigned to body nodes by variation according to the data type and size. Finite state markov model was applied to identify the node state and therefore ensuring average delay during normal and emergency data. However, energy consumption required to resolve the normal and emergency data were not provided. To resolve this issue, Integer Linear Programming was designed in [2] that not only addressed high throughput but also minimized the energy consumption while measuring the physiological parameters.

Physiological parameters are usually correlates with both time and space. The correlation between these two time and space parameters are used extensively for evaluating the faulty for reliable operations and producing diagnosis results in a more accurate manner. To this regard, Haar wavelet decomposition and nonseasonal Holt–Winters forecasting for spatial analysis and the Hampel filter for temporal analysis was provided in [3]. Another energy efficient resource allocation model using Transmission Rate Allocation Policy was designed in [4]. Yet another energy efficiency model to handle optimization of resource allocation was modeled in [5] using Global Energy Minimization (GEM) model.

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Despite, energy efficiency and resource allocation, one of the main issues to be handled is the priority in WBAN. To handle this issue, a Priority-based Cross Layer Routing Protocol was designed in [6] that not only ensured priority but also power consumption. To this the method used slot assignments to handle prioritized data. Another priority-aware scheme was presented in [7] with the aid of pricing-based capacity sharing scheme.

Due to the advantages in mobility, health monitoring services is receiving greater attention for remote monitoring. One of the most appropriate layers to provide QoS in WBANs is the MAClayer. This is because the MAClayer regulates medium access and measures the system performance. In [8], QoS-aware MAC protocol was designed using slot allocation, multi-channel architecture, prioritymechanism, admissioncontrol, andcross-layersolution. However, issues related to lifetime and latency remained unaddressed. An energy efficient MAC was designed in [9] using policy access schemes to extend the network lifetime. Applications and techniques related to WBAN were provided in [10]. Mobile sensor monitoring was provided in [11] using cross layer optimization platform.

The proposed methodis based on the Chapman Kolmogorov Hidden Markov and Energy-efficient Medium Access Layer, and is intended to work on WBAN. It providesQoS support with reduced energy consumption and complexity. The novelty of the proposed method is a Chapman Kolmogorov analysis used to handle different states, in terms of, normal, abnormal and emergency data stages in a more precise manner. The Energy-efficient Medium Access Layeranalysis QoS requirements for transmission delay and energy sensitive packets either sent the packets to the neighbouring nodes or drop the packet based on the states.

The combination of Chapman Kolmogorov Hidden Markov and Energy-efficient Medium Access Layer methodsallows improving the packet delivery ratio by differentiating positive and negative rewards, considering joint probability distribution. Our experimental results show that theproposed method models different states in a more precise manner by considering medium access layer for improving energy efficiency in WBAN.

The rest of the paper is organized as follows. Sections 2 include the related work. Detailed description of our method is provided in Section 3. Section 4 presents the experimental setup for conducting the analysis. In Section 5 the simulation results and detailed description about the packet delivery ratio, transmission delay, energy consumption and the impact of the total number of nodes is provided. Conclusion is given at the end of this paper.

Related Works: Extensive research has been conducted in the developmentof energy efficient protocols forWBANs. A wide investigation model and performance analysis for WBAN was provided in [12]. Taxonomy of QoS for WBAN was provided in [13]. A joint Power-QoS control scheme[14] namely Power QoS Energy Harvesting (PEH-QoS) scheme that interacted in coherence with harvested energy, measuring clinical validity and aggregator and scheduling model was presented to make optimal use of energy and achieve the best possibleQoS.

As the environmental and physiologicaldata collected by sensors in WBAN have differentimportance, providing quality of service (QoS) is a critical issue. In [15], a multiple level-based QoS design for WBAN was provided using mediaaccess control layer by differentiating the data according to the user level, data level andtime level. This in turn achieved energy saving by considering router average priority. Architecture for QoS in WBAN was designed in [16].

Providing scalability and dynamic reconfigurations [17] to meet QoS requirements on network connectivity, packet delivery ratio and end-to-end delay was provided using timed automata model. However, to ensure priority, priority adjustment method was presented in [18] using the characteristic of periodical biomedical signal. Performance management of QoS for biomedical sensor data was presented in [19]. A QoS aware framework using packet queuing and scheduling model was presented in [20].

Based on the aforementioned works, there shows a clear gap in the literature regarding different state models with regards to medium access layer for health monitoring in WBAN. Our work tries to fill this gap by proposing a QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) methodfor health monitoring in WBAN.

MATERIALS AND METHODS

Let us consider a WBAN deployed ina certain area (hospital) for monitoring patient or elderly people. The sensor nodes in WBAN are fixed to the patient's body for sensing information and transmitting the data packets. On the other hand, the sink nodes are deployedfor data packets collection from sensor nodesand forwarding data packets to a medical server for monitoring and diagnosis in an intermittent manner.

In order to improve the health care, one of the most important issues to be handled in WBAN is QoS. In this section, a network model for designing different states with MAC protocol design is presented.

Network Model: Let us consider a WBAN network comprising of e-health users '$U = u_1, u_2,...,u_n$' and a set of Wifi gateway nodes '$G = g_1, g_2,...,g_n$' respectively. Each personal WBAN '$u_i \in U$' aims to disseminate the collected data to the e-health staff through the gateway nodes '$g_i \in G$'.

The main function of WBAN is toensure that data packets be sensed and delivered to the e-health staff through gateway nodes in a more reliable and efficient manner. Thus, quality of service plays an important role in the communication stacks andhas significant impact on the network performance. However, due to the dynamic nature and severe energy constraints inWBAN, predicting and maintaining e-health users information precisely in highly dynamic environments is one of the major issues to be handled. In this paper the foci is made on the medium access layer for energy efficiency and design of hidden markov model to accommodate different states in a more precise manner.

Chapman Kolmogorov Hidden Markov: In this section a Chapman Kolmogorov Hidden Markov (CKHM) is designed to model different states in a more precise manner with QoS support for WBAN. In CKHM, different states are identified through experiences and rewards without the need of maintaining discrete time finite state information [1] and therefore ensuring packet delivery ratio. Let us consider state '$S = \{s_i, = s_1, s_2,...,s_n\}$' and '$s_i$' represents the sensor nodes in WBAN and each sensor node represents a state where '$s \in S$'. The action for the corresponding state is expressed as given below.

$$A = \{a, (s_i, s_j)\}, s_i, s_j \in S \quad (1)$$

From (1) within a specified communication range, execution of '(s_i, s_j)' represent data packet forwarding, from 's_i' to 's_j'. Figure 1 shows the structure of Chapman Kolmogorov Hidden Markov model.

For each agent in a given environment, Chapman Kolmogorov Hidden Markov model includes action 'a', state 's' and reward 'r' respectively. Inspired by [1] discrete time finite Markov model, in particular from different transition states, each node in WBAN is considered as a state '$s \in S$' and for each of its corresponding neighbor nodes 's_i', there is an equivalent action and is expressed as given below;

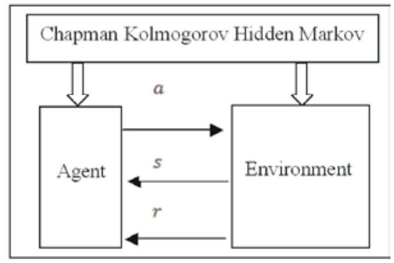

Fig. 1: Structure of Chapman Kolmogorov Hidden Markov model

$$Prog\ (s \rightarrow s, a, DP) = 1 \quad (2)$$

$$Prog\ (s \rightarrow s, a, DP) = 0 \quad (3)$$

From (2), data progression takes place by forwarding the data packets 'DP' by node 's' to corresponding neighbor node 's'. On the other hand, data progression is not said to take place in (3), by holding the data packets 'DP' by the node 's' by itself. Based on the resultant action '1' or '0', the node different states are modeled. These states ranges from either positive rewards, indicating progression, or negative rewards, indicating no progression in addition to the third stage that describes the joint probability distribution using Chapman Kolmogorov which influences the future decisions. The positive rewards and negative rewards are expressed as given below.

$$Prog\ (DP_i) = PR = \left(\frac{Dis\ (s_i \rightarrow sink) - Dis\ (s_j \rightarrow sink)}{Dis\ (s_i \rightarrow sink)}\right) * D_{time}, 1 \quad (4)$$

$$Prog\ (DP_i) = NR = \frac{Dis\ (s_i \rightarrow s_j)}{Dis\ (s_i \rightarrow sink)}, 0 \quad (5)$$

From (4), '$Dis(s_i \rightarrow sink)$' specifies the distance between 's_i' and the sink node '$sink$', whereas '$Dis(s_j \rightarrow sink)$' specifies the distance between 's_j' and the sink node '$sink$' with time delay 'D_{time}' respectively. On the other hand, '$Dis(s_i \rightarrow s_j)$', specifies the distance between the nodes 's_i' and 's_j' respectively. Finally, the joint probability distribution using Chapman Kolmogorov that influences the future decisions is expressed as given below.

$$Prog\ (s_i, s_j)^{a+b} = \sum Prog^{a}_{s_i s_k} Prog^{b}_{s_k s_j} \quad (6)$$

$$Prog\ (s_i, s_j)^{a+b} = Prog\ (s_{a+b} = s_j \mid s_0 = s_i) \quad (7)$$

$$= \sum Prog\ (s_{a+b} = j, s_a = k \mid s_0 = s_i) \quad (8)$$

$$= \sum Prog\ (s_a = k \mid s_0 = s_i) *$$

$$Prog\ (s_{a+b} = j \mid s_a = s_k, s_0 = s_i) \tag{9}$$

$$= \sum Prog^{a}_{s_i s_k} Prog^{b}_{s_k s_j} \tag{10}$$

From (6), by joint probability distribution, different states are more precisely measured, where the reward of an action is process with the aid of an acknowledgement through either positive reward or negative reward. When node 's_j' receive a data packet from node 's_i', 's_j' acknowledges it by sending a positive reward, otherwise by sending a negative reward. By measuring the ratio of the number of positive rewards '*PR*' divided by the number of data packets sent 'DP_i', data packet delivery ratio is obtained. Figure 2 shows the algorithmic description of Chapman Kolmogorov Hidden Markov.

Input: sensor nodes '$s = s_1, s_2, \dots s_n$', action 'a', state 's' and reward 'r', Data Packet '$DP = DP_1, DP_2, \dots, DP_n$'

Output: Improved packet delivery ratio

Begin
  For each sensor nodes 's_i' and 's_j'
    Extract the data packets to be sent
    If '$r = 1$'
      Progression is said to take place as given by (2)
      Measure positive rewards using (4)
    End if
    If '$r = 0$'
      Progression is not said to take place as given by (3)
      Measure negative rewards using (5)
    End if
    Measure joint probability distribution using (6)
  End for
End

Fig. 2: Chapman Kolmogorov Hidden Markov algorithm

The main function of Chapman Kolmogorov Hidden Markov algorithm in WBAN is to ensure that the data packets are sensed and delivered in a more reliable and efficient manner to the medical center. As shown in the figure, for each sensor nodes, the data progression is first analyzed. Followed by this, positive rewards (acknowledgement) or negative rewards (no acknowledgement) is evaluated. Finally, joint probability distribution using Chapman Kolmogorov is measured, providing a platform for analyzing future decision made in a precise manner, ensuring packet delivery ratio.

Energy-Efficient Medium Access Layer: In this section, energy efficient medium access layer based on the result of the data progression achieved through Chapman Kolmogorov is presented to minimize the transmission delay and energy consumption, thereby increasing networklifetime.Energy and transmission delay are considered to be the two of the major setbacks in WBAN. The proposed QoS-CKHM that considers not only the residual energy and but also considers the transmission is presented in this work.

To start with the data packets are received and checked with the MAC address of the packets. Only if the address of the data packet received is same to that of the address of the MAC packets, process is continued. In the proposed Energy-efficient Medium Access Layer model, Transmission Delay Sensitive (TDS) packets and Energy Sensitive (ES) packets are used for modelling a QoS efficient mechanism for WBAN. Figure 3 shows the flow chart ofEnergy-efficient Medium Access Layer.

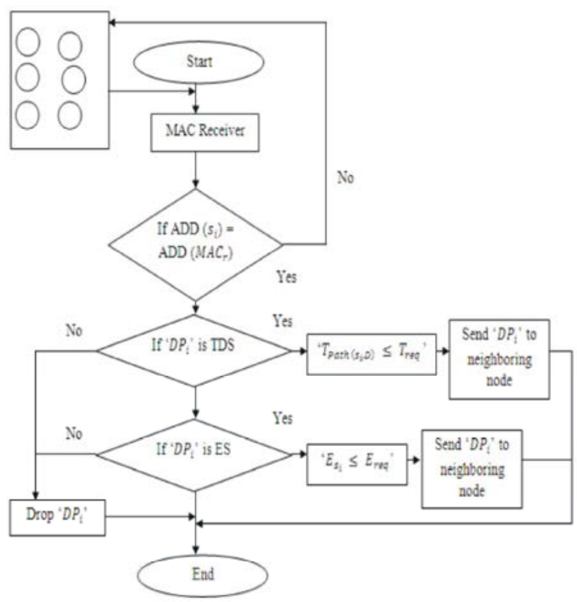

Fig. 3: Flow chart Energy-efficient Medium

Access Layer: To do this, first Transmission Delay Sensitive (TDS) packets are evaluated as provided below, for which the mean successful transmission '*MT*' is obtained as given below.

$$MT = \frac{No_{Ack}}{No_T} \tag{11}$$

From (11), the ratio of number of acknowledgement 'No_{Ack}' and number of transmissions 'No_T' are obtained at regular time interval, where the time interval depending upon the network size. With the observed mean successful transmission, the transmission link time between node 's_i' and neighbor node 's_j', '$TDLink(s_i, s_j$' is measured as given below.

$$T_{Link(s_i,s_j)} = TD_{Link(s_i,s_j)} * MT \quad (12)$$

With the above (12) transmission link time between sensor nodes, the transmission path establishment time (between sensor node and destination node) is obtained as provided below.

$$T_{path(s_i,D)} = T_{Link(s_i,s_j)} * T_{path(s_i,D)} \quad (13)$$

Followed by the establishment of transmission path, energy of sensor nodes are evaluated based on the allocated time slots for each node. The proposed model obtains the ratio of application rate through, number of bits that is sent in one time slot. The number of bits is measured by the product of data rate and slot time and to which the frame length of the sensor node '$fl(s_i)$' is multiplied to obtain the allocated time slot [8]. With this, the Allocated Time Slot 'ATS' for each node 's_i' is mathematically formulated as given below.

$$ATS = \frac{A_{rate} fl(s_i)}{D_{rate} * T_{slot}} \quad (14)$$

From (14), 'A_{rate}' symbolizes the application rate with the frame length of the sensor node being '$fl(s_i)$', data rate and time slot given by 'D_{rate}' and 'T_{slot}' respectively. The energy consumption of the node is calculated, per receivedpacket, for which the allocated time slot is measured. The minimum allocated time slot per received packet for each node ensures minimum energy consumption. Figure 4 shows the Energy-efficient Delay Sensitive algorithm.

The Energy-efficient Delay Sensitive algorithm as shown in figure, evaluates two types of sensitive-aware packets, namely, transmission delay sensitive packets and energy sensitive packets. Based on the incoming nature of the data packets, the QoS classifier classifies the packets into two types. For each data packet, the Energy-efficient Delay Sensitive algorithm checks the transmission path time requirement and energy requirement and based on the result, selects the most appropriate next neighboring hops or returns the data packets and proceeds with other data packets for efficient communication of sensor nodes in WBAN. This in turn reduces the transmission delay and reduces the energy consumption, improving the lifetime of WBAN.

Input: Sensor nodes '$s = s_1, s_2, \dots s_n$', Data Packet '$DP = DP_1, DP_2, \dots, DP_n$', Transmission path establishment time 'T_{req}', Energy requirement 'E_{req}'

Output: Optimized transmission delay and energy consumption

```
Begin
   For each sensor nodes 's'
      If (ADD(s_i) = ADD (MAC_r)
            Measure mean successful transmission using (11)
            Measure transmission link between node 's_i' and neighbor node 's_j' using (12)
            Measure transmission path between sensor node 's_i' and destination node 'D' using (13)
            If 'DP_i is TDS'
               If 'T_Path(s_i,D) ≤ T_req'
                  Send 'DP_i' to neighboring nodes
               Else
                  Drop 'DP_i'
               End if
            If 'DP_i is ES'
               If 'E_si ≤ E_req'
                  Send 'DP_i' to neighboring nodes
               Else
                  Drop 'DP_i'
      Else
Check with other sensor nodes
      End if
   End for
End
```

Fig. 4: Energy-efficient Delay Sensitive algorithm

Table 1: Simulation parameters

Parameters	Values
Deployment area	100m * 100m
Number of nodes	1 sink and 35 sensor nodes
Radio range	40m
Setup time	70ms
Logical topology	Random
Simulation time	400s
Packet length	40bytes
Data transmission rate	250kbps
Number of simulation runs	7

Simulation Setup: To assess the proposed QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) method, a case study in which a WBAN used to monitor 25 patients is tested. In such context, to maximisethe coverage area and at the same time, reduce the transmission delay and the effect of packet delivery ratio to the destination node, WBAN is deployed in a square area. The 36 nodes (1 sink and 35 sensor nodes, one for eachpatient) have a radio range of 40 m is selected to conduct the experiment. After the networksetup time, which is about 70ms, each sensor node startssending data packets at a specific rate. Table 1 shows the detailed description of both the network and the simulationconfigurations.

Experiment is conducted on the factors such as packet delivery ratio, transmission delay, energy consumption, node density, packet size for WBAN. The results of the metrics of QoS-CKHM method is compared against the existing methods such as priority guaranteed MAC protocol [1] and iMproved stable increased-throughput multi-hop linkefficient routing protocol for Wireless Body Area Networks [2] respectively.

Evaluation and Results: To evaluate the proposed QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) method, this section provides several simulationand the corresponding results. To validate the efficiency and theoretical advantages of the QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) method with priority guaranteed MAC protocol [1] and iMproved stable increased-throughput multi-hop linkefficient routing protocol for Wireless Body Area Networks [2], simulation results under NS2 are presented. The parameters of the QoS-CKHM method are chosen as provided in the experiment section.

Impact of Packet Delivery Ratio: Packet delivery ratio '*PDR*' for a given node, is the ratio of the number of packetsreceived successfully at the sink node, divided by thenumber of packets sent by the node. The impact of packet delivery ratio is obtained as given below.

$$PDR = \frac{DP_i \rightarrow sink}{DP_i(s_i)} * Similation\ time \quad (15)$$

From (15), the packet delivery ratio '*PDR*' is measured using the data packets 'DP_i', data packets sent by the senor node 's_i' and the sink node '*sink*' respectively. Higher the packet delivery ratio, more efficient the method is said to be. To better understand the effectiveness of the proposed QoS-CKHM method, extensive experimental results are reported in Table 2. NS2 simulator is used to experiment packet delivery ratio by analyzing the result using table (Table 2) and graph values. In the experiment, different amount of data packet is transmitted at different time interval andthe packet delivery ratio of the proposed QoS-CKHM method is analyzed with that of the priority guaranteed MAC protocol and iM-SIMPLE.Results are presented for different data packet with different simulation time and the results reported here confirm that with the increase in the data packet and simulation time, the packet delivery ratio is also increased.

Packet delivery ratio efficiency results for different data packets with different simulation time between 20s and 140s are given in Figure 5. Each sensor node's residual energy, network transmission range, number of data packets for different analysis of WBANs to cope with packet delivery ratio can be caused by random networks. Inorder to facilitate comparison, in the same environment andat the same time, the QoS-CKHM method and the existing priority guaranteed MAC protocol and iM-SIMPLE methods were analyzed under same simulation setup.

As shown in the figure, the QoS-CKHM method gives better packet delivery ratio than the two other methods priority guaranteed MAC protocol [1] and iM-SIMPLE [2] respectively for different data packets at different simulation time intervals. With forty data packets sent by the sensor node with a simulation time of twenty second, the data packets received at the sink node using QoS-CKHM was found to be thirty two, twenty data packets using priority guaranteed MAC protocol whereas twenty five data packets using iM-SIMPLE. This in turn ensures higher data packet delivery ratio using the QoS-CKHM method. The QoS-CKHM method gives a fifteen percent better packet delivery ratio performance compared to priority guaranteed MAC protocol and twenty three percent better than iM-SIMPLE. The results for the QoS-CKHM method shows an improvement in the packet delivery ratio as it uses a simple Chapman Kolmogorov Hidden Markov model in WBAN classifying the QoSbased on different states (positive rewards, negative rewards, joint probability distribution) in a more precise manner.

Impact of Transmission Delay: Transmission delay is another important metric in WBAN when QoS is concerned. Whenever a source node sends data to the destination, it passes through the sink node, finally reaches the destination node. The transmission delay measures the time taken by each sensor node to reach the destination during data delivery.

$$TD = (Expected_t - Actual_t) * Packet\ length \quad (16)$$

Table 2: Tabulation for packet delivery ratio

	Packet delivery ratio (bytes/second)		
Simulation time (s)	QoS-CKHM	Priority guaranteed MAC protocol	iM-SIMPLE
20	17	14	13
40	28	20	18
60	45	38	34
80	60	52	48
100	80	71	65
120	105	98	90
140	112	100	94

Table 3: Tabulation for transmission delay

	Transmission delay (ms)		
Packet length (KB)	QoS-CKHM	priority guaranteed MAC protocol	iM-SIMPLE
5	21.35	26.48	32.15
10	33.89	38.73	44.63
15	53.14	58.25	64.11
20	74.32	79.43	85.32
25	92.05	97.16	103.54
30	114.32	119.43	125.47
35	132.38	137.49	143.32

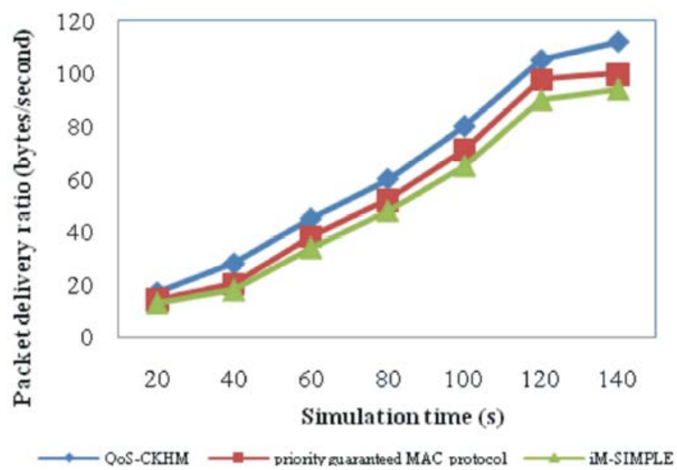

Fig. 5: Comparison of packet delivery ratio

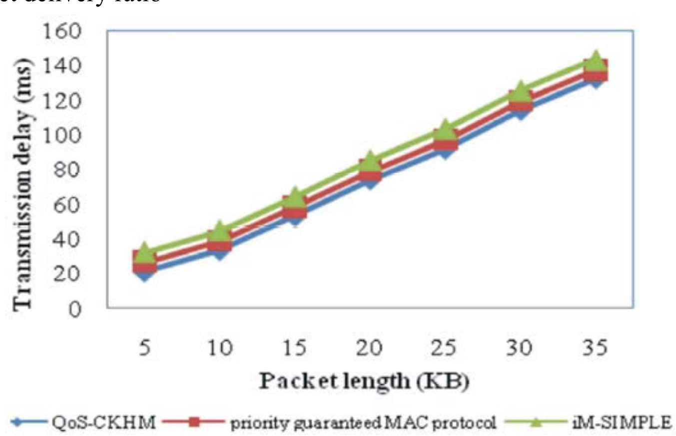

Fig. 6: Comparison of transmission delay

where '$Expected_t$' and '$Actual_t$' stands for the expected time and the actual time in WBAN. The sensor nodes are fixed to thirty five with packet length of 5-35 bytes for seven simulation runs. The performance of all the methods gets better when packet length increases (Table 3). Comparatively, QoS-CKHM method reduces transmission delay since it appropriates the QoS classifier according to the data progression and causes an increase its performance (reduces transmission delay)more than the performance increase of any other methods.

As in the scenario given in Figure 6, a comparison between packet length of 5 bytes and 35 bytes is shown for which the transmission delay is measured. As can be seen when the packet length was 5, transmission delay using QoS-CKHM method was 20ms, 25ms when applied with priority guaranteed MAC protocol and 30ms when applied with iM-SIMPLE.

From Figure 6, it is found that for the QoS-CKHM method withlarge amounts of data transmission for a long time, data packets with different sizes was significantly lower than that in the priority guaranteed MAC protocol and iM-SIMPLE. From the figure it shows that the proposed QoS-CKHM method transmission delay though increased moderately, but when compared to the state-of-the-art works, proved to be better, 10% compared to priority guaranteed MAC protocol and 21% compared to iM-SIMPLE. This is because inEnergy-efficient Medium Access Layer model, incoming data packets are classified according to Transmission Delay Sensitive (TDS) and Energy Sensitive (ES) and according to their results, either the data packet is sent to the neighboring node or discarded. This in turn reduces the transmission delay, because of the classification of data packets and forwarding it according to their results. And the QoS-CKHM method combining sensitive packet details keeps itself more available to the sensor node, so as to the system for the low rate of transmission delay.

Impact of Energy Consumption: To illustrate the performance gain due to Chapman Kolmogorov Hidden Markov and Energy-efficient Medium Access Layer, the performance of energy consumption of QoS-CKHM method is investigated and compared it with priority guaranteed MAC protocol and iM-SIMPLE.

Energy consumption is measured using the energy consumed by a single load (data packets as sent by the source nodes) to the overall loads in WBAN. The energy consumption is mathematically formulated as given below.

$$EC = Energy_{DP} * Total_{DP} \quad (17)$$

From (17), the energy consumption 'EC' at the sink node is obtained by the product of the energy for single data packet sent by the source node '$Energy_{DP}$' and total data packets by all the sensor nodes '$Total_{DP}$' in WBAN during each simulation run. The consumption of energy is measured in terms of Jo*ul*es.The targeting results of energy consumption using QoS-CKHM method with two state-of-the-art methods [1], [2] in table 4 presented for comparison based on the node density.

In Figure 7 the comparison between the conventional QoS energy aware method and the proposed QoS-CKHM method is seen with respect to energy consumption. As can be observed, as the node density increases, the Energy-efficient Delay Sensitive algorithm tends to measure the transmission between the sensor node and neighbor node, measure transmission path between sensor node and destination, based on the sensitive packet types and activate the data forwarding through the sink nodes. This results in the desired data forwarding, providing large savings during data delivery. The model as designed is therefore able to reduce the energy consumption for different packets of varying size for differing node density.

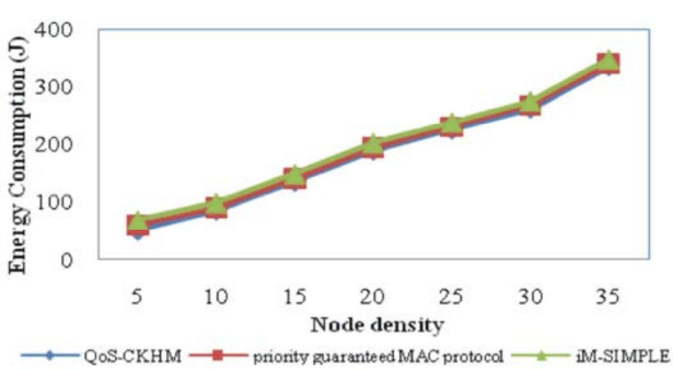

Fig. 7: Comparison of energy consumption

Table 4: Tabulation for energy consumption

	Energy Consumption (J)		
Node density (SN)	QoS-CKHM	Priority guaranteed MAC protocol	iM-SIMPLE
5	50	59	68
10	85	90	98
15	135	140	148
20	189	194	202
25	225	230	238
30	262	267	275
35	335	340	348

The transmission path establishment time and allocation of time slots as described by energy-efficient medium access layer, with optimal strategy, resultsin the reduced energy consumption in QoS-CKHM method. With the application of energy-efficient medium access layer, mean successful transmission is obtained based on the acknowledgement and number of transmit resulting in the reduced energy consumption. With the mean successful transmission, the source node sends the data packets on the basis of transmission delay and energy delay sensitive packets, whereas in the conventional models, the data packets passes through all the sensor nodes and thereby increases the energy consumption. With the separation of data packets, the sink node performs data forwarding in WBAN to the corresponding server. This in turn reduces the energy consumption using QoS-CKHM method by 5% compared to priority guaranteed MAC protocol [1] and 12% compared to iM-SIMPLE [2] respectively.

CONCLUSION

A novel QoS aware Chapman Kolmogorov Hidden Markov (QoS-CKHM) method is proposed for health monitoring service in WBAN. The modules of QoS-CKHM method are divided into two main types: Chapman Kolmogorov Hidden Markov and Energy-efficient Medium Access Layer. The Chapman Kolmogorov Hidden Markov modules include theMAC receiver, measure positive rewards, negative rewards and joint probability distribution. The transmission delay sensitive packets, energy delay sensitive packets areincluded in Energy-efficient Medium Access Layer.The proposed QoS-CKHM method provides a mechanismwith the help of Chapman Kolmogorov Hidden Markov algorithm and Energy-efficient Delay Sensitive algorithm that obtains the mean successful transmission, transmission link time and allocated slot with the consideration of QoS requirement. Simulations were conducted to measure the performance of the proposed method. Thesimulation results showed that the QoS-CKHM method had better performancein excess of 19% packet delivery ratio when compared withpriority guaranteed MAC protocol and iM-SIMPLE respectively.

REFERENCES

1. Muhammad Babar Rasheed, NadeemJavaid, Muhammad Imran, Zahoor Ali Khan, Umar Qasim and Athanasios Vasilakos, 2015. “Delay and energy consumption analysis of priority guaranteed MAC protocol for wireless body area networks”, Springer, Wireless Networks, December 2015, pp: 1-18.
2. Nadeem Javaid, Ashfaq Ahmad, QaisarNadeem, Muhammad Imran and Noman Haider, 2015. “iM-SIMPLE: iMproved stable increased-throughput multi-hop link efficient routing protocol for Wireless Body Area Networks”, Elsevier, Computers in Human Behavior, 51: 1003-1011.
3. Osman Salem, Yaning Liu, Ahmed Mehaoua and Raouf Boutaba, 2014. “Online Anomaly Detection in Wireless Body Area Networks for Reliable Healthcare Monitoring”, IEEE Journal Of Biomedical And Health Informatics, 18(5): 1541-1551.
4. Zhiqiang Liu, Bin Liu, Chang Chen and Chang Wen Chen, 2015. “Energy-efficient Resource Allocation with QoS Support in Wireless Body Area Networks”, IEEE Global Communications Conference (GLOBECOM), December 2015, pp: 1-6.
5. Xiaoli Zhou, Tingting Zhang, Liyuan Song and Qinyu Zhang, 2014. “Energy Efficiency Optimization by Resource Allocation in Wireless Body Area Networks”, IEEE 79th Vehicular Technology Conference (VTC Spring), May 2014, pp: 1-6.
6. Hadda Ben Elhadj, Jocelyne Elias, Lamia Chaari and Lotfi Kamoun, 2016. “A Priority based Cross Layer Routing Protocol for healthcare applications”, Elsevier, Ad Hoc Networks, 42: 1-18.

7. Changyan Yi, Zhen Zhaoa, Jun Cai, Q1 Ricardo Lobato de Faria, Gong (Michael) Zhang, 2016. "Priority-aware pricing-based capacity sharing scheme for beyond-wireless body area networks", Elsevier, Computer Networks, 98: 29-43.
8. Abdullah Sevin, Cuneyt Bayilmis and Ismail Kirbas, 2016. "Design and implementation of a new quality of service-aware cross- layer medium access protocol for wireless body area networks", Elsevier, Computers & Electrical Engineering Available online 18 February 2016, pp: 1-12.
9. Anil K. Jacob and Lillykutty Jacob, 2015. "Energy Efficient MAC For Qos Traffic In Wireless Body Area Network", Hindawi, International Journal Of Distributed Sensor Networks, January 2015, pp: 1-12.
10. Rim Negra, Imen Jemili and Abdelfettah Belghith, 2016. "Wireless Body Area Networks: Applications and technologies", Elsevier, Procedia Computer Science, 83: 1274-1281.
11. Norbert Varga, Laszlo Bokor and Andras Takacs, 2014. "Context-aware IPv6 Flow Mobility for Multi-Sensor based Mobile Patient Monitoring and Tele-consultation", Elsevier, Procedia Computer Science 40: 222-229.
12. Nourchene Bradai, Lamia Chaari Fourati, Lotfi Kamoun, 2014. "Investigation and performance analysis of MAC protocols for WBAN networks", Elsevier, Journal of Network and Computer Applications, 46: 362-373.
13. Shah Murtaza Rashid Al Masud, 2013. "QoS Taxonomy towards Wireless Body Area Network Solutions", International journal of Application or Innovation in Engineering Management, 2(4): 221-234.
14. Ernesto Ibarra, Angelos Antonopoulos, Elli Kartsakli, Joel J.P.C. Rodrigues, Senior and Christos Verikoukis, "QoS-aware Energy Management in Body Sensor Nodes Powered by Human Energy Harvesting", IEEE Sensors Journal, 16(20: 1-8.
15. Long Hu Yin Zhang Dakui Feng Mohammad Mehedi Hassan Abdulhameedlelaiwi and Atif Alamri, 2015. "Design of QoS-Aware Multi-Level MAC-Layer forWireless Body Area Network", Springer, Journal of Medical Systems, December 2015, pp: 1-11.
16. Lamia Chaari, Lotfi Kamoun, 2011. "QoS Concepts and Architecture Over Wireless Body Area Networks for Healthcare Applications", International Journal of E-Health and Medical Communications, October-December 2011, pp: 50-51.
17. Simon Tschirner, Liang Xuedong and Wang Yi, 2008. "Model-Based Validation of QoS Properties of Biomedical Sensor Networks", EMSOFT '08 Proceedings of the 8th ACM international conference on Embedded software, January 2008, pp: 69-78.
18. KIM Jinhyuk, SONG Inseong and CHOI Sangbang, 2015. "Priority-based adaptive transmission algorithm for medical devices in wireless body area networks (WBANs)", Springer, Journal of Central South University, May 2015, 22(5): 1762-1768.
19. Dheerendra S. Gangwar, 2011. "Traffica Ndp Erformancem Anagementf Orb Iomedicals Ensorn Etwork", International Journal of Computer Science and Communication, 2(1): 183-189.
20. Xuedong Liang and Ilangko Balasingham, 2007. "A QoS-aware Routing Service Framework for Biomedical Sensor Networks", International Symposium on Wireless Communication Systems, October 2007, pp: 342-345.