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Nonlinear Agent Routing Technique for Efficient Wireless Body Area Network Communication

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Abstract: Wireless Body Area Networks (WBANs) is the collection of small sensor nodes that are used to monitor the human body condition. WBANs are effectively employed in healthcare area like e-health, remote patient monitoring and health monitoring of soldiers in battlefield. Routing in WBAN is essential part for sending the data packets to the sink node with minimum energy consumption and energy drain rate. However, the end to end delay between sensor nodes remained unaddressed. In order to reduce the end to end delay, Non-Linear Agent Routing Technique (NLAR) is designed in WBAN. NLAR technique in WBAN collects the sensed data from different nodes and classifies the sensed data packets based on the emergency and normal conditions. Then, NLAR technique performs single hop or multi-hop communication based on the nature of data to reduce the end to end delay and energy consumption. Finally, NLAR technique routes the data packets to the sink node in an efficient manner. NLAR technique also helps to reduce the energy consumption with minimum energy drain rate. Performance results shows that the proposed NLAR technique obtains the better performance in terms of end to end delay, energy consumption and energy drain rate as compared to the state-of-the-art works.

Key words: Wireless Body Area Networks · Remote patient monitoring · Non-Linear Agent Routing · Sensor nodes · Routing · Single hop communication · Multi-hop communication

INTRODUCTION

Wireless Body Area Networks (WBANs) increases need of the healthcare service for improving the quality of patient's life. In WBAN, every small biomedical sensor nodes are inserted inside the human body for collecting the vital signs of human body. After collecting the information, the source node sends the information to the sink node with minimum medical and healthcare cost. Routing in WBAN has attracted the attention of researchers. Many routing techniques consider the heterogeneous behaviour characteristics of data proposed during the last decade. In [1], an agent based healthcare monitoring system using four agents namely, admin agent, control agent, query agent and data agent was designed which helps in the development of the data traffic. Though, the end to end delay between sensor nodes remained unaddressed. For addressing the issue, an agent-based model using star-based design was planned in [2] with better activity recognition accuracy. But, the energy consumption rate is high.

In [3], Multi Attribute Decision Making (MADM) methods reduce the packet overhead and number of handovers depending on network history and user preference. In addition, an integrative platform called Integrated Health Monitoring System (IHMS) based on multi-agent model was designed in [4] and also increased the elder's life quality. But, optimization remained unaddressed. Applications and techniques of WBAN were studied in [5]. Mobile sensor monitoring in [6] uses cross layer optimization platform. However, the energy drain rate is high in mobile sensor monitoring.

An integer linear programming model was designed in [10] presented energy and cost efficient WBAN model. However, multi objective remained unaddressed. For better scalability and dynamic reconfigurations [7] to meet

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QoS needs on network connectivity, packet delivery ratio and end-to-end delay was presented in timed automata model. Though, to ensure priority, priority adjustment method was designed in [8] by characteristic of periodical biomedical signal. In [9], an energy efficient method was planned for securely and reliably transmitting messages from sensor nodes to medical server which is monitored by medical personnel. However, transmission time consumption is high.

In this paper, Non-Linear Agent Routing Technique (NLAR) is designed in WBAN to perform energy efficient routing. First, based on the classification of generated data by the sensing agent, classification of emergency and normal data packets is done. Then, non-linear agent model is applied to the classified data packets and routed in an efficient manner. The routing is carried out either through single hop or multi hop according to the emergency constrained data packets by the communication agent resulting in the improvement of energy consumption and end to end delay.

In the rest of this paper, Section 2 reviews the related work and Section 3 elaborates the contributions of the proposed framework, Non-Linear Agent Routing Technique (NLART). Section 4 presents the experimental results and discusses their significance in Section 5. Section 6 finishes the paper with concluding remarks.

Related Works: WBANs face many challenges like quality of service requirements that are to be solved before the final implementation in telemedicine systems. In [13], a joint power-QoS control scheme was introduced by optimal energy usage with the best possible QoS. In addition, QoS-based management scheme was designed in [14] depending on the average filter movement that leads to the enhancement of the patient monitoring ratio.

Due to the mobility tasks, health monitoring services is receiving large interest for remote monitoring. The most appropriate layers to provide QoS in WBANs are MAC layer. MAC layer regulates medium access and calculates the system performance. In [12], QoS-aware MAC protocol was planned by slot allocation, multi-channel architecture, priority mechanism, admission control and cross-layer solution. However, lifetime improvement and latency issues remained unaddressed. An energy efficient MAC was designed in [15] by policy access schemes for increasing the network lifetime. But, the packet delay remained unaddressed.

In [16], an energy consumption model regarding transmission distance and transmission data rate over wireless communication link was designed for guaranteeing the energy saving and improving the proportion of transmission energy. A Virtualization Enabled routing [17] was designed for reducing the traffic congestion and packet delay. Though, classification accuracy was not at required level. Mahalanobis-Taguchi System (MTS) based classification [11] was planned to improve the classification accuracy. A new method was designed in [18] for providing better energy efficiency with help of an integer programming model. In [19], Bayes node energy polynomial distribution model was introduced for guaranteeing the minimum communication overhead. A truthful online channel sharing algorithm was designed in [20] to assign the channel efficiently without any misrepresentation of their channel parameters. Based on the above mentioned methods and techniques, Non Linear Agent Routing Technique is designed to provide an appropriate solution to solve the existing issues.

Nonlinear Agent Routing Technique: Wireless Body Sensor Network (WBSN) consists of biomedical sensor nodes 'S_i' inserted inside the human body and a sink node 'SN' is considered. The designed framework by intra WBSN is modeled as a connectivity graph 'G' as given below.

$$G = (V, E) \tag{1}$$

From (1) 'V' denotes the vertices forming edges 'E'. The vertices 'V' denotes the union of all biomedical sensor nodes 'S_i' and sink node 'SN' through intermediate nodes 'IN_i' respectively represented as given below.

$$V = \{S_i\} \cup \{SN\} \cup \{IN_i\} \tag{2}$$

From (1) and (2), edges 'E' represent set of wireless link between any two biomedical sensor nodes, the intermediate nodes are '$In_i = IN_1, IN_2,...,IN_n$' in the network and the sink node. Each edge with weights denotes the network parameters where each biomedical sensor nodes knows the neighboring nodes and sink node positions. Figure 1 show the structure of WBAN used in the Non-Linear Agent Routing Technique (NLAR) consisting of a source sensor node, a sink node and intermediate nodes through which efficient routing is performed.

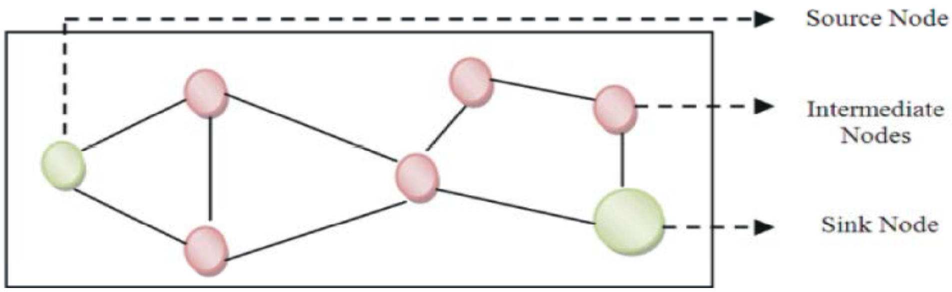

Fig. 1: Structure of WBAN

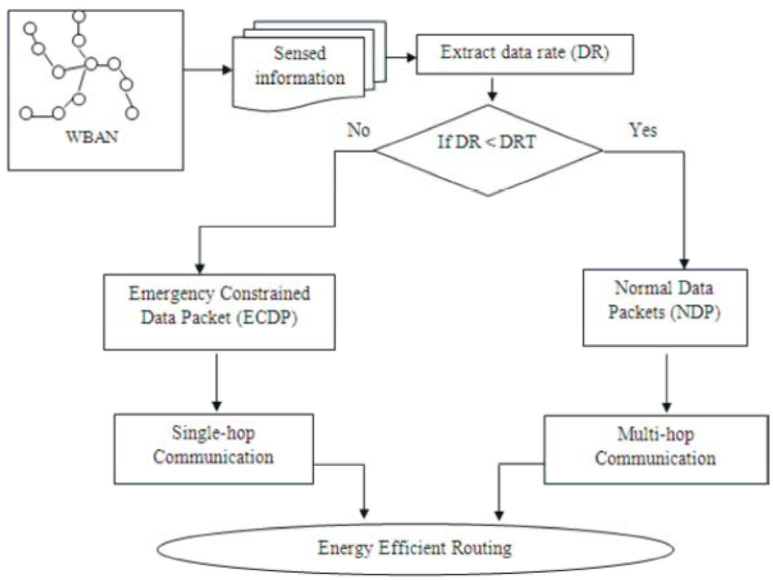

Fig. 2: Structural Diagram for Classification and Routing of Data Packets

The biomedical sensor nodes in WBAN is energy-constrained which senses the information and forward the sensed data to neighboring biomedical sensor nodes 'S_i'. In addition, intermediate nodes 'IN_i' routes the information to the sink node '*SN*'. The key objective is to find the optimal distances during routing with minimal consumption of energy for all sensors in WBAN.

Data Packets Classification in WBAN: The key objective of Non-Linear Agent Routing Technique (NLAR) in WBSNs is to address the need of an Emergency Constrained Data Packets (ECDP). Let the emergency is taken as the QoS constraint, NLAR technique classifies the collected data packets into Emergency Constrained Data Packets (ECDP) and Normal Data Packets (NDPs) as shown in Figure 2.

The ECDPs sends the data packet directly to the sink node for reducing the end to end delay time. The generated data from electrocardiography (ECG), electroencephalography (EEG) and so on is taken as examples of ECDPs. NDPs do not impose such type of constraint therefore the NLAR technique uses multi hop communication by non-linear routing.

The wireless body sensor nodes in the network are not arranged at equal distance from each other which results in minimum end to end routing delay during the multi hop communication for NDPs. Some of the examples of NDPs include pulse count, blood pressure blood sugar and so on. Routing followed through single hop and multi hop is explained in the following section.

Non-Linear Agent Single Hop Routing Technique for ECDPs: Non-Linear Agent for single hop communication manages many patients' health monitoring at the same time with minimal energy consumption for ECDPs in WBAN. Energy consumption of single hop communication for ECDPs by 'E_{SH}' is expressed as given below.

$$E_{SH} = E_{DP} + E_{amp} * d \quad (3)$$

From (3), the energy consumption for single hop communication is attained by adding the energy consumed by the data packet 'E_{DP}' and energy consumed by transmission amplifier 'E_{amp}'. 'd' represents the distance between source node and sink node. In similar manner, with large amount of data packet (i.e. information) extraction for handling multiple patients' health monitoring, a Non-Linear model for single hop communication '$SHC(E_{SH})$' is presented and expressed as given below.

$$SHC(E_{SH}) = b * (E_{DP} + E_{amp} * d) * E_i \quad (4)$$

From (4), 'b' represents the bits transmitted for 'i' WBAN sensor nodes with 'E-' symbolizing the energy loss during transmission.

Non-Linear Agent Multi Hop Routing Technique for NDPs: Non-Linear multi hop communication handles multiple patients' health monitoring in a simultaneously manner with minimal energy consumption for NDPs in WBAN. The energy consumption of multi hop communication for NDPs using 'E_{MH}' is expressed as given below.

$$E_{MH} = E_{DP} + E_r \quad (5)$$

From (5), 'E_r' represents energy consumed for data reception. For collecting and studying the multiple patients' information in WBAN, Non-Linear Multi Hop Routing Technique $MHC_i(E_{MH})$ is carried out with minimal energy consumption.

$$\sum_{i=1}^{n} MHC_i(E_{MH}) = b * (E_{DP} + E_r * d^i) \quad (6)$$

From (8), 'd^i' represents the distance between i[th] sensor nodes to the neighboring node. The time gets increased as information moves through all intermediate nodes. The process is repeated for all the multiple patients to identify the best route. Figure 3 shows the Emergency Constrained Data Packets-based classification and Routing of biomedical sensor data.

As shown in Figure 3, for each biomedical sensor nodes, the Biomedical Sensor Data Classification algorithm classifies the data based on the nature of data (i.e. emergency or normal data). The data rate of every WBAN sensor nodes is collected and compared with

Input: biomedical sensor nodes 'S_i', Data Rate 'DR', Data Rate Threshold 'DRT',
Output: Minimum end to end delay and reduced energy consumption

Begin
For each biomedical sensor nodes 'S_i'
Obtain data rate 'DR'
If 'DR' < 'DRT'
Data packets considered as 'NDP'
Perform multi hop communication 'MH' using (6)
Else
Data packets considered as '$ECDP$'
Perform single hop communication 'SH' using (4)
End if
End for
End

Fig. 3: Biomedical Sensor Data Classification and Routing algorithm

Data Rate Threshold value. After the resultant comparison value, single hop communication or multi hop communication is carried out based on the nature of data. Biomedical Sensor Data Classification and Routing algorithm is to reduce the end to end delay and energy drain rate during the transmission of the packets. For this, the ECDP are routed through single hop whereas the NDPs are routed through multi hop. In addition, multiple patients' information is handled for ECDP and NDPs using Non-Linear Agent model.

Experimental Settings: Non-Linear Agent Routing Technique (NLAR) is implemented in NS-2 simulator with the network range of 1500 * 1500m size. The sensors in WBANs are used to examine the patient's activities with efficient routing mechanism. The mobile network consists of 500 nodes in the network structure and uses the Random Way Point (RWM) model. The RWM uses typical number of mobile nodes for locating the movable nodes. The dynamic changing topology uses the Dynamic Source routing (DSR) protocol to implement efficient energy management and secured data communication between the source and sink node in WBAN. The node speed is varied between 2m/s and 25m/s with the mobile node pause time is varied from 0 seconds to 300 seconds. Table 1 shows the simulation parameters for different performance metrics.

Table 1: Simulation parameters

Node density	50,100,150,200,250,300,350,400,450,500
Network area	1500*1500m
Transmission range	250m
Packets	9, 18, 27, 36, 45, 54, 63
Simulation period	600s
Minimum node speed	2m/s
Maximum node speed	25m/s
Node pause time	0 - 300 seconds
Routing protocol	Dynamic source routing protocol (DSR)

Simulation Results and Analysis: The NLAR technique is compared against the existing Multi Agent System (MAS) [1] and Agent Oriented MAPS framework [2]. The experimental evaluation is carried out with the different parameter such as end to end delay, energy consumption and energy drain rate compared to the state-of-the-art works. Performance is evaluated based on following metrics with the help of tables and graph values.

Impact of End to End Delay: End to end delay is defined as the duration between the time at which the initial bit of packet is transferred from source node and the time at which the last bit of the similar packet is received by sink node. The end to end delay is measured in terms of milliseconds (ms).

$$\text{End to End delay } (ms) = \text{Starting time of first bit of the packet} - \text{recieving time of last bit of same packet} \quad (7)$$

Table 2 shows the end to end delay with respect to packet number ranging from 9 to 90 in simulation area. When the number of packet gets increased, the delay also gets increased correspondingly. But, the end to end delay of proposed NLAR technique is comparatively lesser than that of the MAS [1] and Agent Oriented MAPS framework [2].

From Figure 4, the simulation results of end to end delay are presented for different number of packets. The emergency constrained data packets are classified into normal and emergency constrained data packets based on the data rate which results in minimum end to end delay in proposed NLAR technique. In NLAR technique, classification of normal and emergency data packets at various time intervals is depending on data rate comparison made with the data rate threshold (DRT) in an efficient manner. The sensing agent senses the information and sends the sensed information to the sink node in WBAN. This in turn reduces the end to end delay using NLAR technique by 31% compared to MAS [1] and 56% compared to Agent Oriented MAPS framework [2] respectively.

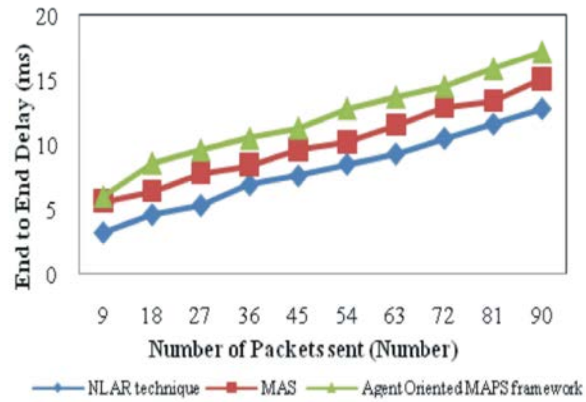

Fig. 4: Measure of End to End delay

Impact of Energy Consumption: Energy consumption is calculated through analyzing many nodes (i.e., patients) and transmitting amplifiers. It is measured in terms of Joules (J). The energy consumption is defined as the energy consumed for sending the information to the sink node from the source node.

$$EC = \sum_{i=1}^{n} S_i * (E_{INi} + E_{amp}) \quad (8)$$

In the above equation, 'S_i' represents the number of nodes in WBAN and 'E_{INi}' represents the energy consumed for identifying intermediate nodes and 'E_{amp}' is the energy consumed by transmit amplifier.

Table 3 describes the measurement of energy consumption based on node density. The energy consumption of proposed NLAR technique is reduced while increasing the node density compared to existing MAS [1] and Agent Oriented MAPS framework [2].

Figure 5 shows comparative analysis for energy consumption with respect to different number of nodes with existing MAS [1] and Agent Oriented MAPS framework [2]. The increasing nodes in the range of 50 to 500 are taken for experimental purpose in NLAR technique. As shown in figure, initially, 50 nodes were taken and the proposed LP-SE framework consumed 253J energy. But, the energy consumption of existing MAS and Agent Oriented MAPS framework was found to be 365J energy and 501J energy respectively. Due to, the non-linear single hop and multi hop routing technique used in proposed technique for sensing the information to the sink node from the source node, the energy consumption gets minimized. Therefore, the energy consumption of NLAR technique is 27% and 63% lesser compared to existing MAS [1] and Agent Oriented MAPS framework [2] respectively.

Table 2: Tabulation for End to End delay

	End to End Delay (ms)		
No. of Packets Sent (Number)	NLAR technique	MAS	Agent Oriented MAPS framework
9	3.2	5.6	6.0
18	4.6	6.4	8.6
27	5.3	7.8	9.6
36	6.9	8.4	10.5
45	7.6	9.6	11.3
54	8.5	10.2	12.8
63	9.3	11.5	13.7
72	10.5	12.9	14.5
81	11.6	13.4	15.9
90	12.8	15.1	17.2

Table 3: Tabulation for Energy Consumption

	Energy Consumption (J)		
Number of Nodes (Number)	NLAR Technique	MAS	Agent Oriented MAPS framework
50	253	365	501
100	365	456	658
150	456	562	785
200	500	687	895
250	562	752	954
300	658	841	1056
350	789	963	1145
400	852	1085	1285
450	965	1156	1365
500	1056	1247	1456

Table 4: Tabulation for Energy Consumption

	Energy Drain Rate (J)		
Number of Nodes (Number)	NLAR Technique	MAS	Agent Oriented MAPS framework
50	35	46	58
100	45	52	62
150	59	63	72
200	66	76	85
250	75	89	93
300	84	95	106
350	92	109	119
400	105	116	124
450	112	124	136
500	123	135	149

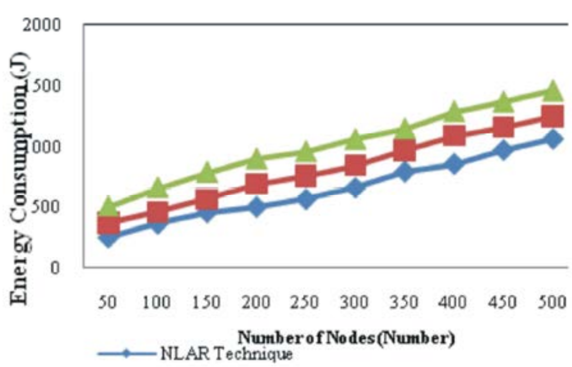

Fig. 5: Measure of Energy Consumption

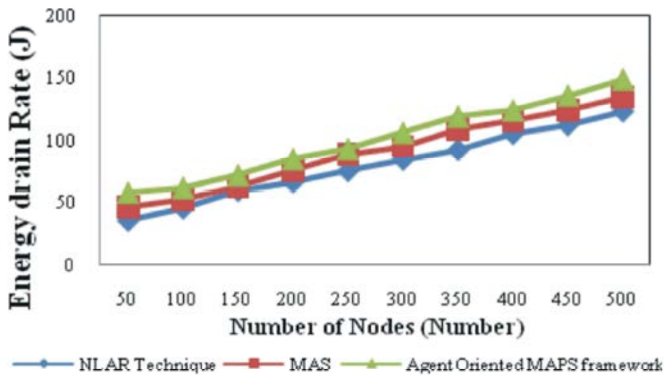

Fig. 6: Measure of Energy Consumption

Impact of Energy Drain Rate: Energy Drain Rate is the measured which integrates the drain rate metric into routing process. EDR is used to predict lifetime of nodes consistent with current traffic conditions. The consumption of energy is measured in terms of Joules.

Table 2 describes the measurement of energy drain rate based on number of nodes. The energy drain rate of proposed NLAR technique is reduced while increasing the number of nodes compared to existing MAS [1] and Agent Oriented MAPS framework [2].

Figure 6 clearly describes the measurement of energy drain rate with respect to different number of nodes with existing MAS [1] and Agent Oriented MAPS framework [2]. The energy drain rate is calculated when the energy gets dissipated at particular node. Every node in network monitors the energy consumption and maintains battery power drain rate value by taking the mean value of energy consumption and calculating the energy dissipation per second. Compared to the MAS [1] and Agent Oriented MAPS framework [2], the proposed NLAR technique has less energy drain rate because the existing methods consumes large amount of energy while sending the information to the sink node. In addition, the energy drain rate in NLAR technique is 15% and 29% lesser when compared to MAS [1] and Agent Oriented MAPS framework [2] respectively.

CONCLUSION

A Non-Linear Agent Routing Technique (NLAR) is designed for efficient routing the information to the sink node from the source node in Wireless Body Area Network (WBAN). Initially from the generated data, the data gets classified into emergency constrained data packets and normal data packets by comparing the data rate with the data rate threshold. Then, Non-Linear Agent Single Hop Routing Technique is carried out for emergency constrained data packets in WBAN with minimum end to end delay. In addition, Non-Linear Agent Multi Hop Routing is carried out for normal data packets in WBAN which in turns reduces the energy consumption. Finally, the data packets are sent to the sink node in energy efficient manner. The performance of NLAR technique is measured in terms of end to end delay, energy consumption and energy drain rate while routing the information to the sink node in WBAN and compared with MAS [1] and Agent Oriented MAPS framework [2]. With the simulations conducted for NLAR technique, it is observed that the end to end delay gets minimized as compared to state-of-the-art works. The simulations results shows that NLAR technique provides better performance by reducing the energy consumption by 45% and energy drain rate by 22% when compared to state-of-the-art works.

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