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Life Span Improvement of Bio Sensors Using Unsupervised Machine Learning for Wireless Body Area Sensor Network

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ABSTRACT

Wireless body area networks (WBAN) are a popular subfield of wireless sensor networks used for continuous patient monitoring. WBAN is a network of many sensor nodes fused in and around the body to detect a patient's physical and behavioral activities and periodically send data to the base station, which may lead to the degradation of the energy efficiency of Biosensors. The authors proposed energy-efficient clustering methods using unsupervised learning in the present study. Ten sensor nodes were deployed on various parts of the human body using the OMNET++ simulator for analyzing multiple parameters using a systematic or query-based approach. The clustering approach is finalized based on the cluster head and obstacles in the deployment area. By reducing the number of packets, reception, and transmission, the sensor nodes can be disseminated, which improves the biosensors' lifetime. The number of rounds and network lifetime was studied by changing biosensors' critical parameters like first node death. The outcome was compared with the existing clustering protocols and found that the proposed protocol has been observed to increase network life span compared to the existing approaches, which will help to design an intelligent health monitoring system.

1. INTRODUCTION

According to the WHO report, as of 22 May 2022, over 522 million confirmed cases and over six million deaths have been reported globally. Save a patient's life requires emerging technology-based medical equipment and medical services within a period. One of the efficient methods of modern medical technology is Virtual Medical Organization (VMO) which communicates with physicians & medical organizations to remotely monitor the patient and share resources wireless using body area networks (WBANs) made of various intelligent biosensors.

Critical care patients are intermittently monitored, with the frequency varying according to the patient's sickness, and some of the monitoring is based on physical examination and direct observation. Other monitoring is continual and constant, given by sophisticated equipment that someone with specialized training and experience must operate. Most of these devices sound alert when certain physiologic thresholds are reached. The procedures for looking into alarms should be adequately adhered to in every intensive care unit (ICU).

Vital indicators (temperature, blood pressure, pulse, and respiration rate), total fluid intake and output, and frequently daily weight are all typically monitored. Ha et al. [1] provide details about placing the biosensor nodes such as thermocouple (TC) sensor and electrocardiography (ECG) sensor they are used for measuring the heart rate and body temperature measurement. The placement of ECG can be on the armpit, chest, and back thigh, and the TC sensor on the thumb, finger, and ear. The biosensor, located on the patient body parts to the base station for the process, is used to cause the energy consumption of the biosensor and reduces its lifetime [2, 3]. In most cases, the biosensors deployed on the patient capture the patient's movement in the hospital and process the data by Emergency Medical Technicians (EMTs), nurses, or physicians [4]. The WBAN technology can be implemented in a hospital or patient's home to improve the tracking of the attributes related to disease, monitoring the diagnosis, health care delivery, and related medical procedures. Also, WBAN helps reduce the infection spread through wireless communication. These devices in the wireless area network are invasive, which need to be implanted in the person, and noninvasive, which can be worn by the person. Healthcare applications require highly accurate predictions on a real-time basis for their decision-making. The various algorithms used by the clustering in WBN to increase its lifetime by reducing the energy consumption of biosensors are as follows, in the study [5], the M-ATTEMPT algorithm is used to form clusters using cost function and increases the lifetime of biosensors and the death of the first biosensor after more number of rounds and time. Alsheikh et al. [6] uses Machine learning (ML) techniques to perform routing, processing, and clustering. In this way, it is used to provide energy-efficient protocol and increases the life span of the biosensors. It is evaluated using a MATLAB simulator and compared with MELM, PRDA, PNNDA, and LEACH protocols. Khan et al. [2] uses ML to compress the data sent to the cluster head. The amount of data communication within the cluster is reduced by using filtering. To reduce the energy consumption of the biosensor, it uses filtration and reduces the load on the cluster head [4]. Mohanty and Kabat [7] use a technique based on the priority the data is communicated within the cluster to reduce energy consumption. Authors [8] reduce the energy consumption by transmitting the value to the cluster head only if it varies from its previous value. It stored the last value and comparison with it. It uses a genetic algorithm to find the shortest path for communication and reduce energy consumption, but it contains high complexity. Yan et al. [9] uses the concept of the Artificial Bee to provide optimal communication, but it is applicable for mesh topology. Nazeer et al. [10] provide a mechanism for reducing the number of packet transmissions and reception using the L and S algorithm. It provides a new protocol for data-centric routing where the sink will generate a query and forward it to all the sensor nodes. The nodes fulfilling the constraint of the question will respond to the sink by using an optimized energy approach and increase a network lifetime. Ramamurthy et al. [11] provides a mechanism for optimized cluster head selection by considering constraints like energy, distance, and hop count. Xu and Manman [12] use a Genetic Ant-based approach to reduce energy consumption, but the drawback of this approach is its complexity. Agnihotri and Gupta [13] provides a protocol that increases the lifetime of the sensor nodes by up to 23% by using a hybrid PSO-GA scheme, but energy management has not been done correctly. Javaid et al. [14] efficiently uses the power and provides more value to the throughput, but the problem is that there is no synchronization between the sensor nodes. Zhao et al. [15] uses agglomerative nesting, i.e., hierarchal clusters for the clustering. It considered the scenario of both homogenous and heterogeneous nodes for selecting the cluster head and increasing the lifetime of the sensor nodes. Xian et al. [16] provides details about the simulation and comparison among various routing protocols by considering mobile nodes and evaluating them using multiple performance metrics in numerous situations. Based on the survey, most of the existing protocols like [2, 4, 10] for WBAN have been implemented for biosensor nodes with a static environment without taking into consideration whether the biosensor is homogenous or heterogeneous. Zhao et al. [15] consider both, but they are complex. We consider a biosensor is deployed on the patient, and they form a cluster to send the data to the sink. Here, we can consider both homogenous and heterogeneous biosensors with static and moving/mobile environments. Jaber and Idrees [17] provides the importance of increasing the wireless biosensors for health monitoring and the role of ML techniques in the health domain. Liu et al. [18] discusses optimizing the current techniques of WBAN and its dependencies of biosensors in the future healthcare domain. Supritha Devi et al. [19] provide details of using supervised ML techniques to automate the system instead of doing it manually. Existing literature shows that ML is frequently used to develop wearable devices [20] and the Internet of Things (IoT) with ML is used to detect diseased conditions [21]. Hence it is necessary to convert the manual health monitoring system to an automated health monitoring system.

This proposed article aims to make the energy-efficient utilization of the biosensor nodes in the health domain to make an automated patient monitoring system by overcoming the drawback of reducing the energy consumption by the biosensor nodes and increasing the lifetime using unsupervised ML. The authors proposed an unsupervised machine-learning technique of clustering, forming the cluster, selecting the optimized cluster head, and predicting the lifespan of the biosensor. Section I provide a detailed description of the introduction and literature survey. Section II describes ML. Section III, Results and Discussion Section IV Conclusion and Future work.

2. MACHINE LEARNING

ML is one of the essential components of Artificial Intelligence (AI), and in the last two decades, it has gained more attention in all areas of engineering and social problems. Most Regression, Classification, Clustering, graph-based problems, and Heuristic search problems can be solved using supervised, unsupervised, semi-supervised, and reinforcement learning. The proposed system used two unsupervised learning-based algorithms based on the cluster head and obstacles K-means, K- Harmonics (KHM). In the proposed study authors consider ten different sensor nodes on various body parts of humans for sensing multiple body parameters as shown in Figures 1 and 2. These values are sensed and transmitted by the sensor nodes using two methods. While performing simulation, we generate scaler and vector files for single-patient and multi-patient models using a homogenous and heterogeneous biosensor. This data can be used as training data for the linear regression model to predict the life span of the biosensor for that environment. In the future, we want to obtain the data set from various resources to train the model to predict the life span of the biosensor in various situations and environments. In the proposed system, ten different sensor nodes are placed on various body parts of the patient for detecting multiple body parameters such as temperature, blood pressure, pulse, etc., as shown in Figures 1 and 2. These values are sensed and transmitted by the sensor nodes using two methods.

2.1 Single patient model

In this model, the biosensor sends the data directly to the sink; it will be efficient if the distance between the biosensor and sink is less, but as the distance increases, energy depletion increases. The sink's performance also depends upon the number of biosensors sending the data. If a large number of biosensors send the data, it reduces sink performance too. To increase the life span of biosensors, we proposed below two methods.

1. Systematic method: The biosensor will sense and transmit the value based on the regular time interval. as shown in the figure below, it will send its value directly to the sink.
2. Query method: The sensor node will sense the value based on the sink's query. It is an optimization approach in which the life span of the biosensor is increased by performing data transmission and reception based upon

the query sent by the sink. It will not sense the value continuously as in the systematic method.

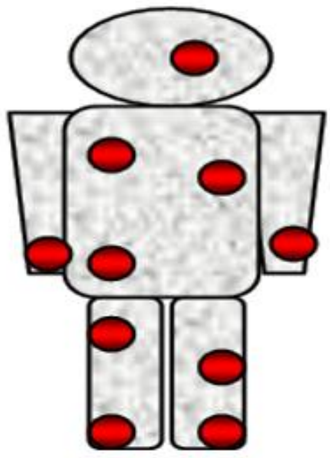

Figure 1. (a) Single patient

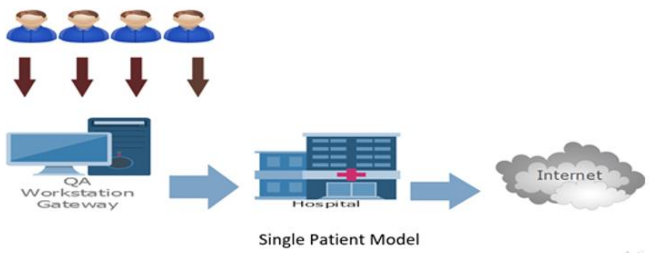

Figure 1. (b) Deployment of bio-sensor on human in the single patient model

2.2 Multi-patient model

In this model, the biosensor forms clusters and sends the data to the local cluster head. It will be efficient as the distance between the biosensor and cluster head is always minimum. The sink's performance also increases as only the cluster head will send the data to the sink. To increase the life span of biosensors, we proposed below two methods.

1. Periodic method: The biosensor will sense and transmit the value based on the regular time interval. as shown in above Figure 1, it will send its value directly to the cluster head shown in Figure 2.
2. Query method: The sensor node will sense the value based on the sink's query. It is an optimization approach in which the life span of the biosensor is increased by performing data transmission and reception based upon the query sent by the sink. It will not sense the value continuously as in the systematic method.

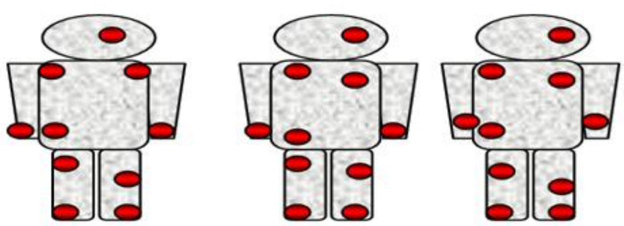

Figure 2. (a) Multi-patient

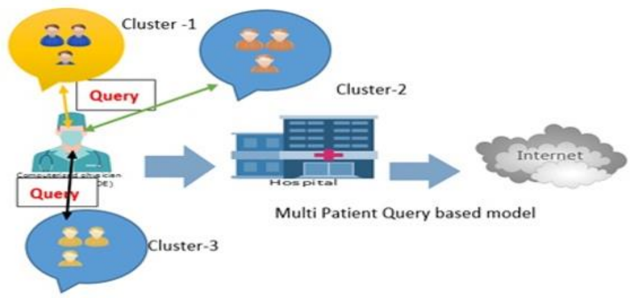

Figure 2. (b) Deployment of bio-sensor on human in the multi-patient model

2.2.1 Cluster head selection

We have provided two different mechanisms for selecting the cluster head based on the deployment area. If we are creating the multi-patient model in an environment with obstacles, then the cluster head selection is made using the K harmonic mean, and in the absence of obstacles, the cluster head selection is made using the K Mean approach. It has been observed that the selection of the cluster head based upon obstacle presence will affect the lifespan of biosensors. We have evaluated both approaches by considering homogeneous and heterogeneous nodes. The quantification model of this paper has been published by considering various scenarios. The cluster head selection mechanism uses the approach of Leveling and Sectoring algorithm [10] for homogenous nodes. The heterogeneous nodes cluster head selection is made [11].

Based on the situation of the patients, the medical team will decide whether they will use periodic or query-based methods. Each method has its advantages and disadvantages, as shown in Table 1.

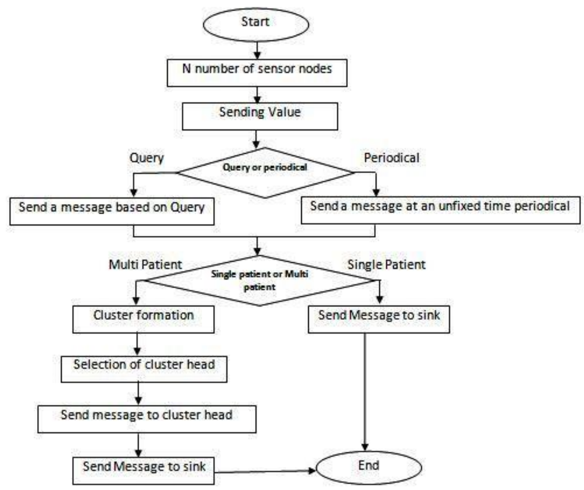

Figure 3. Flow chart of the proposed model

Figure 3 provides details about the two strategies that can monitor the patients using a periodical or query-based approach for the single and multi-patient model. From Figure 3, it is clear that in the case of the single-patient model, the final message from the sensor is sent to the sink while in the case of the multi-patient model the three additional steps are performed for cluster formation, selection of cluster, cluster head, and send message to cluster head was introduced. If a sensor has minimum distance and maximum energy compared to the entire nodes in the existing system, then it will be selected as a forwarder node. Multi-hopping is used to reduce data communication distance and save energy consumption. The authors proposed following unsupervised MLbased algorithms for creating clusters and optimizing cluster head selection mechanisms to minimize distance and energy consumption.

Table 1. Types of the patient model

Single patient model (SPM)	Multi patient model
Minimum cost	The cost will be more than SPM
Lifetime depends upon a periodic model or query-based model	Increases lifetime of sensor nodes
Simple for implementation	It uses a clustering concept that is a bit complex
Suitable for small-scale health center	Ideal for large-scale health center

Algorithm single patient model

Start
Step 1: TI, BS //TI: = Time interval //BS: = Biosensor
Step 2: Periodic () //function
If (TI is true) // check condition
BS → generate →reading →sink //the bio sensor send value to the sink
End if
Step 3: Query based () //function
If (query is satisfied by BS) // check condition
BS → generate →reading →sink //the bio sensor send value to the sink
End if
End

Algorithm Multi patient model

Start
Step 1: TI, BS //TI: = Time interval
TH: = Threshold Energy
BS: = Biosensor
CH: = Cluster Head
CM: = Cluster members
Step 2: Cluster formation () //function
BS from cluster → k-mean // without obstacle
BS from cluster → KHM // with obstacle
Step 3: CH selection () //function
for BS 1 to n // checking the energy level and distance of bio sensor
BS energy > TH & BS distance == centroid
Selected as CH
End of for
Step 4: Periodic () // function
If (TI is true)
BS → generate →reading →CH
End if
Step 5: CH→ Sink
Step 6: Query based () //function
If (query is satisfied by BS/CM)
BS → generate →reading →CH // bio sensor sends values to cluster head
End if
CH→ Sink
End

3. SIMULATION

The simulation has been done by using the OMNET++ 5.5.1 simulator, which is well-defined in WSN, WBAN, and VANET [22, 23]. The existing EERP [23], MLM [24], and proposed K-Mean and KHM [24, 25] have been simulated by considering various nodes, as shown in Table 2. The protocols have been evaluated by considering multiple performance metrics such as first-node death, last-node death, number of packet transmissions, and the dissimilation of the energy. The detailed procedure of depletion of the biosensor energy model is shown in Figure 4.

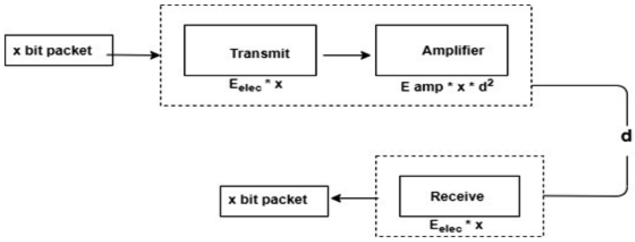

Figure 4. Depletion of biosensor energy model

Table 2. Simulation parameters

Parameter	Values
E_{elec}	16.7nJ/bit
e_{amp}	1.97pJ/bit
E_{comp}	36.1nJ/bit
DATA size	2000 bit
Num. of nodes (N)	10-50
Initial Battery charge	3.0 J
Sensed area	50 m 2

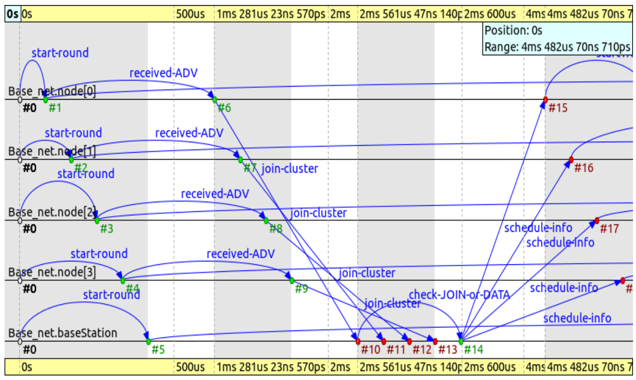

Figure 5. Communication messages between the nodes

The biosensor is deployed using the (x, y) coordinates on various body parts. The value of the coordinates has been initialized by using the uniform function, which is used to provide the random number, and it has been ensured that no two sensor nodes get the exact coordinates values, as shown in Figure 5. The sink will send a query directly to the sensor nodes using the advertisement message in a single patient model. The biosensor will send a reply to the sink using a data message. The transmission of the messages between the sink and biosensor is shown in Figure 6. Its values are recorded in the scalar file, and the dissemination of the energy due to data transmission and reception has been recorded in the vector file. The various messages exchanged between the cluster members and the cluster head before the dispatch of the actual data are shown in Figure 6.

The node that wants to act as cluster head will send the advertisement message to all the sensor nodes. The nodes wished to become as the cluster member will send the reply back to the cluster head by using the join cluster message, then the cluster head will send the scheduler message to cluster members, the time at which it can send the value to the cluster head in the periodic method, whereas in the query-based process it sends data based upon the query received from the cluster head. The dissemination of the node's energy occurs due to the following operation, and dissemination is evaluated using the formulas as per Eqns. (1)-(3).

Table 3. Symbolic description

Symbol	Description
E_t	Transmission energy
E_r	Reception Energy
E_D	Data transmission energy
Select	Circuit energy
e_{amp}	Transmitter amplifier energy
$E_{co\ map}$	Computational energy
X	Number of bits
N	Number of messages
D	Distance

$$E_t = E_{elec} * x + e_{amp} * x * d^2 \quad (1)$$

$$E_r = E_{elec} * x \quad (2)$$

$$E_D = E_{comp} * x * n \quad (3)$$

Eq. (1) is used to indicate the amount of energy depletion that occurs when the transmission of the data occurs by the biosensor. Eq. (2) represents the depletion of energy that occurred while receiving the packet from the biosensor/sink. Eq. (3) indicates the amount of energy required for compressing the data. Table 3 provides the symbolic description of the symbols used for the quantification model.

4. RESULT AND DISCUSSION

Below mention, Tables 4, 5, and 6 provide the reading obtained from the scalar files by simulating the proposed K-Mean, KHM (K Harmonic Means), and existing protocols (EERP, MELM) by varying the number of nodes. Table 5 reading shows that the First Node Death (FND) occurs after the same number of rounds in the existing protocol which is shown in Figure 6. Even though the number of nodes has been increased, they are identical, whereas the number of rounds in the proposed protocol of K Harmonic Means, (KHM) is more due to the efficient utilization of the biosensor's energy. It can be seen that the first node death occurs after more rounds in KHM than in the K-Mean. Table 6 shows the simulation result with a variation in the number of nodes when the Last Node Death (LND) occurs after more time in the existing protocol with the increase in the number of nodes, but its end node dies in less time than the proposed protocol; therefore, the proposed protocols increase the biosensor lifespan. It can also be seen that the LND occurs after more rounds in KHM than in the K-Mean. The graphical representation of the simulation result is shown in Figure 7. Another observation is the number of packet transmissions is identical in the existing protocol with the increase in the number of nodes, but as packet transmission increases with the increase in the number of nodes in the proposed protocol. It can be seen that the packet transmission also increases in KHM than the K Mean which is shown in Figure 8.

Table 4. Simulation result of FND

Nodes	Existing	K Means	KIM	MEL
10	13020	11900	16500	14010
20	13020	7507	17400	15143
30	13020	6222	18420	16238
40	13020	5326	19002	17112
50	13020	5100	20900	11834

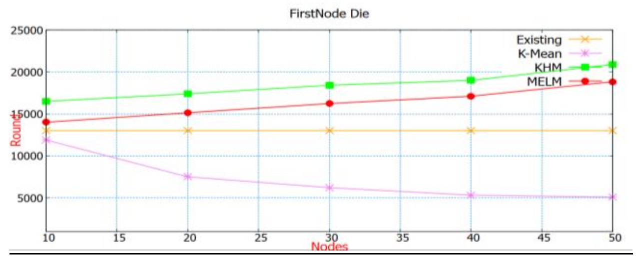

Figure 6. First node death

Table 5. Variation of nodes with FND

Nodes	Existing	K Means	KIM	MEL
10	15624	16766	20014	15910
20	18228	20906	25701	19230
30	20832	25350	32612	23010
40	22213	27512	38145	24910
50	24024	29015	43012	27198

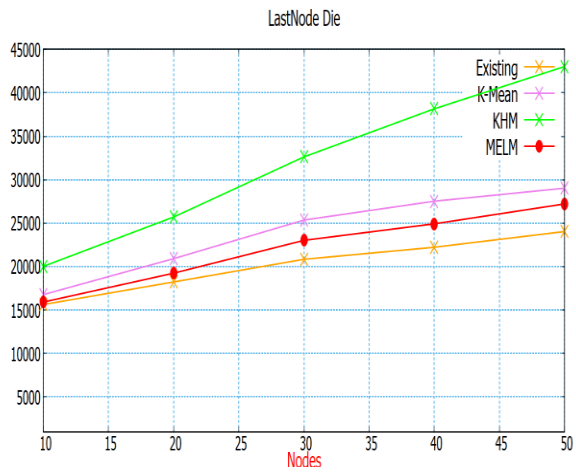

Figure 7. Last node death

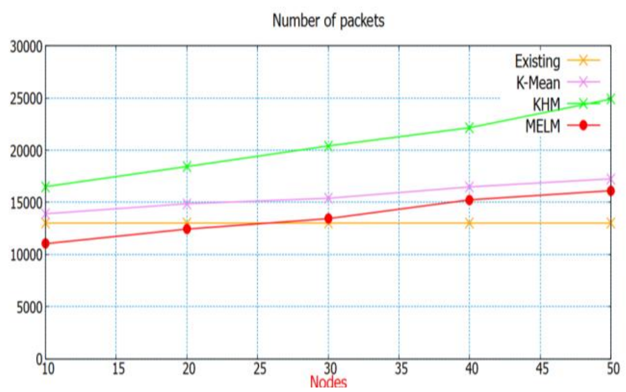

Figure 8. Number of packets

Table 6. Variation of nodes with LND

Nodes	Existing	K Means	KIM	MEL
10	10321	13896	16500	11034
20	10321	14861	18425	12430
30	10321	15381	20400	13429
40	10321	16472	22145	15230
50	10321	17249	24894	16112

4.1 Comparison between proposed and existing protocol by varying coverage regions of biosensor

From Figures 9 and 10, it is clear that if the range of the sensor nodes is increased from 50 to 400 meters square for communication in single-hop rather than multi-hop. The first node death after more rounds in the coverage region of 50 meters, but if it has been increased to 100, there is a sudden decrease in the number of rounds in both the existing and proposed protocols. Therefore, the number of rounds of the sensor nodes depends upon the coverage region, and the number of rounds in the proposed protocol is more than the existing as shown in Table 7 below.

Figure 9. First node death

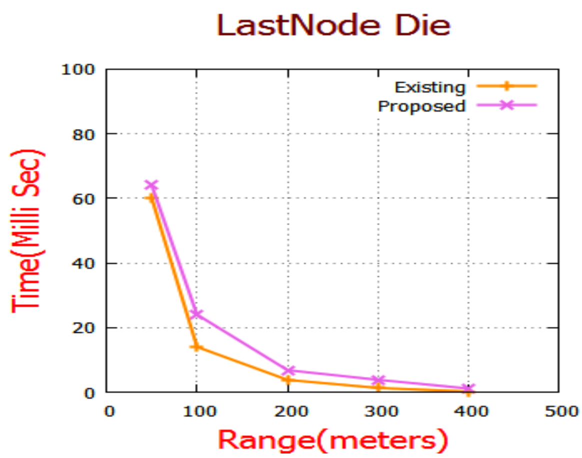

Figure 10. Last node death

To better understand the relation between the energy consumption number of sensor nodes and different approaches, simulation is performed for FND, LND, and a combination of both by varying the number of sensor nodes at the interval of 50 ranging from 50-250 at fixed 1-joule energy. Data collected from the simulation are shown in Tables 8-10 and graphical representation is shown in Figures 11, and 12. From Table 8 and Figure 10 it is clear that, if the number of sensor nodes increases, the current system to energy depletion is static, as energy depletion is less in K-Means and KHM. First, Node death occurs after more rounds in KHM compared to K-Mean and existing protocols. Last node death occurs after more K-Mean rounds than KHM and existing protocols. Therefore, K-Mean can be utilized in the application where it requires more biosensor lifespan and does not bother about the first biosensor node death. Several data packets occur more in number in K-Mean than in KHM and existing protocols. Therefore, K-Mean can be utilized in applications requiring more biosensor lifespan and packet transmission.

Table 7. Simulation result of first node death and last node death by changing the range of sensor nodes

Edge/Range	Existing		Proposed	
	FND	AND	FND	AND
50	50	60	57	64
100	12	24	6	24
200	3	3	8	6
300	1	1	4	3
400	0	0	2	1

Table 8. Simulation result of first node death and last node death by changing the number of sensor nodes

Nodes	Existing	K Means	KIM	MEL
50	50	53	72	52
100	50	65	100	59
150	50	76	148	62
200	50	64	159	68
250	50	74	223	186

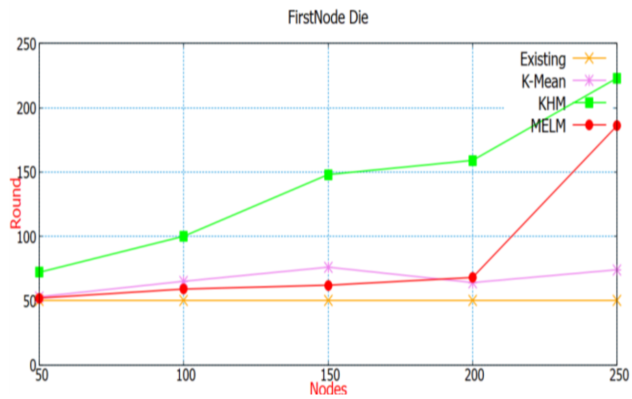

Figure 11. First node death

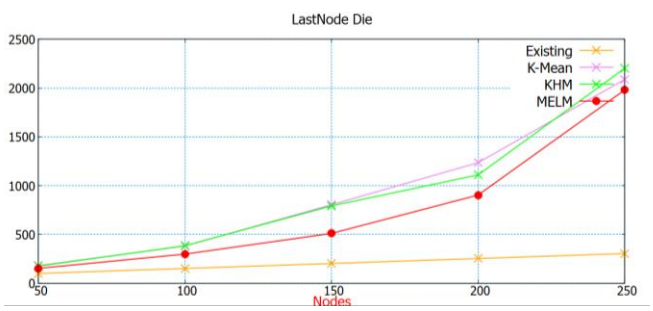

Figure 12. Last node death

Table 9. First node death and last node death by changing the number of sensor nodes

Nodes	Existing	K Means	KIM	MEL
50	100	180	174	152
100	151	381	384	298
150	202	804	792	510
200	253	1235	1110	903
250	304	2088	2202	1980

Table 10. First node death and Last node death by changing the number of sensor nodes

Nodes	Existing	K Means	KIM	MEL
50	51	90	83	72
100	51	127	126	98
150	51	201	188	150
200	51	247	220	198
250	51	348	322	290

4.2 Comparison between proposed and various existing protocols by using homogenous and heterogeneous biosensors

In the proposed study authors obtained simulated results by randomly deploying the ten biosensors on patients at various positions. The simulation has been done using the OMNET++ simulator and compared with the metrics mentioned in Tables 11 and 12. From Table 11 it is clear that the proposed algorithm is increasing the network life span up to 96.90% in the case of homogeneous biosensors at 0.5J, which is better than the existing available literature. In the case of heterogeneous biosensors, there is a significant improvement in the FND, LND, and number of rounds. The proposed algorithm has been observed to reduce energy consumption and increase the network life span in the case of homogenous and heterogeneous biosensors.

Table 11. A performance comparison between the five clustering protocols in the homogeneous networks (the initial energy at 0.5 J)

References	Protocol	First node death (Milli sec)	Last node death (Milli Sec)	Number of rounds	Network Life Span
[2]	LEACH	30	173	204	94.5%
[2]	PRADA	34	186	210	96%
[2]	PNNDA	39	204	190	90%
[8]	Artificial bee Colony	45	230	241	95%
[11]	Ant colony Algorithm	42	244	220	96.76%
Proposed	Proposed algorithm	54	259	256	96.90%

Table 12. A performance comparison between the five clustering protocols in the heterogeneous networks (the initial energy at 0.3-0.5 J)

References	Protocol	First node death (Milli Sec)	Last node death (Milli Sec)	Number of rounds
[2]	LEACH	18	195	210
[2]	PRADA	23	210	220
[2]	PNNDA	29	220	215
[8]	Artificial bee Colony	30	245	243
[11]	Ant colony Algorithm	32	234	230
Proposed	Proposed algorithm	45	260	240

5. CONCLUSION

This paper presented a clustering method to optimize energy consumption and increase the life span of the wireless body sensor nodes by reducing unnecessary packet transmission and reception. The authors proposed two models, single-patient and multi-patient, depending on the hospital based on the query, and packet transmission and reception decided by the medical staff depending upon the patient. The proposed algorithm reduces energy consumption by reducing the number of packet transmissions and reception. We compared the proposed and existing algorithms using performance metrics such as first biosensor death, last biosensor death, and the number of times the biosensor sent the data to the sink in several rounds.

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