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MEDIA-WSN: Multi-Objective Energy and Distance Integrated Algorithm in Wireless Sensor Network

M. Muthuselvi[1]*

[1]*Department of Computer Science and Engineering,*
University College of Engineering (Anna University Constituent College), Nagercoil, India
* Corresponding author's Email: muthuselvi456m@gmail.com

Abstract: Wireless sensor networks (WSNs) are appealing contemporary trends that are dispersed throughout the natural world to analyse the information they receive. The information can be sensed and transmitted more effectively by the sensor nodes. Numerous energy-efficient routing techniques were proposed in earlier research to speed up the network by reducing energy consumption frequently, the sensor nodes quickly run out of power. Most recent articles discuss various techniques aimed at lowering energy consumption in sensor networks. In this paper a novel Multi-objective energy and distance integrated algorithm (MEDIA-WSN) has been proposed to routing /clustering technique with low distance and energy consumption. The MEDIA-WSN method has two phases namely cluster head phase, and routing phase for providing security and energy efficiency. In the first phase, the cluster head selection has been done by using honey badger algorithm which consider the fitness parameters of the sensor nodes such as energy consumption and network lifetime. In the second phase, the routing has been done by using improved spider monkey optimization algorithm which calculate the fitness parameters such as distance, energy consumption and network lifetime. From the simulation analysis, the MEDIA-WSN model overall energy consumption (210 J), packet loss rate (0.5%), packet delivery ratio (99.6%), and end-to-end delay (10 s). The proposed MEDIA-WSN model improves the overall energy consumption of 60.74%, 81.3%, an 85% than EADCR, MOCRAW, and FCEEC techniques respectively.

Keywords: Cluster head, Wireless sensor networks, Honey badger algorithm, Improved spider monkey optimisation algorithm.

1. Introduction

The WSN is a node that includes sensors, transceivers, processing power, and other components, which uses autonomous networks of rechargeable wireless sensors that can good sense, manipulate, and interact, has become a promising tool for monitoring the physical world [1, 2]. It can be quickly and affordably set up, allowing for massive, upon request tracking and evaluation across a variety of applications such as threat notification, automobile surveillance, combat scene observation, ecosystems inspection, etc [3]. A WSN is typically constructed using a large number of node sensor arrays that are distributed at arbitrarily throughout the area of detection. Additionally, non-traditional models are needed for WSNs due to constraints in source security, architecture, and protocols [4, 5]. These nodes receive regional tangible information, analyse it, and send it to a BS or subside. To spread understanding of the event, the BS is connected to the internet. The ability of the nodes to cooperate is yet another crucial component of a WSN.

The most widely used method for maintaining WSN topology is clustering [6, 7]. A clustering method arranges the nodes into a set of groupings known as clusters which improve the life of the network. Based on a strict set of predetermined standards, such as community load balancing, high-satisfactory service, and resource intake that improves the way of life in the community [8]. The CH node of one cluster can communicate with the CH node of any other cluster through inter-cluster interaction [9, 10]. Instead of transmitting raw data to the data fusion node, sensor nodes employ their computational capacity to perform computations and merging operations locally, providing just the data that are necessary [11, 12]. These characteristics are used in wireless sensors for a range of programmes, including surveillance and observation.

Environment estimation, the security industry, and different applications in business and industry are just a few of the uses for WSNs [13]. When compared to one network, a distributed WSN has the advantage of being able to carry out more complex tasks over an expanded region and for an additional amount of time. When a computer system works with its adjacent nodes, it consumes its individual assets, such as technology energy as well as electricity [14]. Insufficient powered by battery nodes that are sparsely sent in inhospitable or faraway places make up WSNs used for ecological tracking. However, the constrained power resources of the sensor nodes in WSNs are the core issue. It is impossible to resupply or substitute the nodes' batteries once they have completely used up their energy because they are frequently deployed in hostile environments [15].

In the WSN operation process, the information gathering and network energy consumption is a difficult process that affects the reliability of the WSN [16]. To enhancing the WSN technique the routing method, proper CH selection and security problems are the major issues under consideration. So, in this paper a novel multi-objective energy and distance integrated algorithm (MEDIA-WSN) has been proposed to routing/clustering technique with low distance and energy consumption.

The main aim of the MEDIA-WSN method is given as follows:

- The MEDIA-WSN method has two phases namely CH Selection phase, and Routing phase for providing security and energy efficiency.
- Initially, the cluster head selection has been done by using Honey Badger Algorithm which consider the fitness parameters of the sensor nodes such as energy consumption and network lifetime.
- The routing has been done by using Improved Spider Monkey Optimization Algorithm which calculate the fitness parameters such as distance, network lifetime, and energy consumption.
- Finally, by using less energy, data packets will securely travel the shortest distance to their destination and have a longer network lifespan.

As a result, the remaining portions of this research paper is mentioned as follows: Section II, the literature survey of current energy-efficient WSN routing & cluster techniques, problem statement is provided. In section III states the introduction and the system model of the proposed method, the block diagram and an explanation of the proposed strategy are presented. Section IV describes the simulation results along with a comparison of the suggested approach are presented. Section V illustrates the conclusion of this proposed method.

2. Literature survey

WSN performance such as energy use, network lifetime, throughput, transmission delay or packet delay, percentage of packets lost, etc., has been the subject of many research. Several swarming and transportation strategies have recently been developed for WSN energy consumption. A review of the most recent research and approaches looking at this issue was given in this section.

In 2021, Panchal, A. and Singh, R.K., [17] suggested the EADCR protocol to lengthen the life of WSNs that use the FCM technique. FCM technique can select the CH based on fitness function, but not in efficient way. Additionally, it offers a fresh method of routing packets utilising the shortest path method between a node and its destination. The simulation findings show that, in comparison to other existing algorithms, the EADCR extends the network lifetime.

In 2023, Chaurasia, S., K. Kumar, and N. Kumar [18] suggested a MOCRAW to reduce node energy usage and facilitate quick data transmission with high dependence on input parameter settings. It utilised the Dragonfly Algorithm to create loop-free routing. In comparison to other clustering and routing protocols, MOCRAW performs better in terms of average energy usage, packet delivery ratio, and delay. The outcome demonstrates that MOCRAW outperforms its contemporaries and rivals in terms of energy efficiency.

In 2022, Jagan, G.C. and Jesu Jayarin, P., [19] introduced a FCEEC strategy that uses shortest path routing from SN to CH in a multihop setting. This method uses the electrostatic discharge algorithm. FCEEC improves the overall performance like energy efficiency, packet delivery, and network latency but resulting in duplicated node selection and low selection precision.

In 2022, Yadav, R.K. and Mahapatra, R.P., [20] suggested an energy-conscious, new hierarchical routing method for WSN CH selection with substantial expenses when used in networks with a

Table 1. Notations

Notation	Definition
Yu	Upper bounds
Yl	Lower bounds
Y_{new}	new position of honey badger
β	the capacity of an insect to gather food
F	prey
Di	distance information
σ	Density parameter
r	present iteration
r_{max}	overall number of iterations
C	constant
$sm_{new}\, j$	generation of trial position
$fitness_i$ and $MaxFitness$	fitness for the entire population

large number of nodes. The hybrid PDU-SLnO algorithm combines the principles of the particle swarm optimisation (PSO) and sea lion optimisation (SLnO) algorithms. Finally, the efficiency of the adopted approach is assessed in relation to particular metrics in contrast to other ways currently in use.

In 2020, Baradaran, A. A. and Navi, K., [21] suggested an HQCA-WSN to produce high-quality clusters. The intra-cluster and inter-cluster distances are improved, and the clustering error rate is decreased to the application of a criterion for determining cluster quality. Additionally, both internal and external criteria are used to evaluate the clustering quality. The results show that the HQCA-WSN method improves network lifetime and energy consumption, but does not improve optimal cluster estimate based on the density and periphery density of every node.

In 2020, S. Umbreen, D. Shehzad, N. Shafi, B. Khan, and U. Habib., [22] suggested a mobility-based cluster head selection system that is energy-efficient for load balancing and CH selection. The selection of CH is influenced by a number of factors that significantly affect how much energy the sensor uses. The experimental result demonstrates that in terms of load balancing, energy depletion, network stability, and throughput, the proposed EEMCS performs better than other existing methods. To forecast the motion of sensor nodes that are not useful in selecting the most mobile stable CH.

In 2022, M. Wu, Z. Li, J. Chen, Q. Min, and T. Lu [23] developed a DCK-LEACH based on K-means and Canopy optimization. This method uses a hierarchy to lessen the workload on cluster heads and balance the network strain. Determine CH using the residual energy of the node and the distance between the node and BA. The results show that, in comparison with existing approaches, the DCK-LEACH method increases the lifetime of energy-critical nodes, the network lifetime, the extremely fast energy consumption, and the unbalanced energy consumption of nodes.

According to the review of the literature, a various current techniques include drawbacks such as malicious attacks, battery range limitations, energy usage, and network lifetime when transferring data to destinations. In order to increase the lifespan of the system, this research creates MEDIA-WSN based routing and clustering approaches for WSNs. These algorithms reduce the energy utilised by the sensors on each node.

3. MEDIA-WSN methodology

WSNs need to achieve optimal load control and distribution to extend network service life and energy consumption. In this paper, a low-power, low-distance clustering/routing technique, multi-objective energy-distance integration algorithm (MEDIA-WSN), was proposed. The MEDIA-WSN scheme consists of two phases: cluster head phase and routing phase to ensure security and energy efficiency. Cluster head selection was done using the Honey Badger algorithm. The algorithm considers sensor node suitability parameters such as energy consumption and network lifetime in the first phase. Routing is performed using an improved spider monkey optimization algorithm, and in the second phase, suitability parameters such as distance, energy consumption, and network lifetime are calculated. Eventually, the data packets arrive safely at their destination. Fig. 1 shows the overall MEDIA-WSN methodology. The notation has been represented in Table 1.

3.1 Honey badger (HB) algorithm for cluster head selection

Initially, the sensor nodes are calculated a fitness value such as power usage and network lifetime, based on the values the cluster head selection has been done by using honey badger algorithm (HB). The HBA features are discussed in detail for cluster head selection. The way honey badgers forage had an impact on the design of the HBA. The honey badger employs digging as a secondary approach in addition to using its sense of smell to find its prey. The first strategy was referred to as the "digging phase," while the second tactic was referred to as the "honey phase" by the algorithm's creators. The honey badger's sense of smell regulates its movements; when the scent is strong, it will move swiftly, and vice versa. The clustered sensors are given as input to the honey

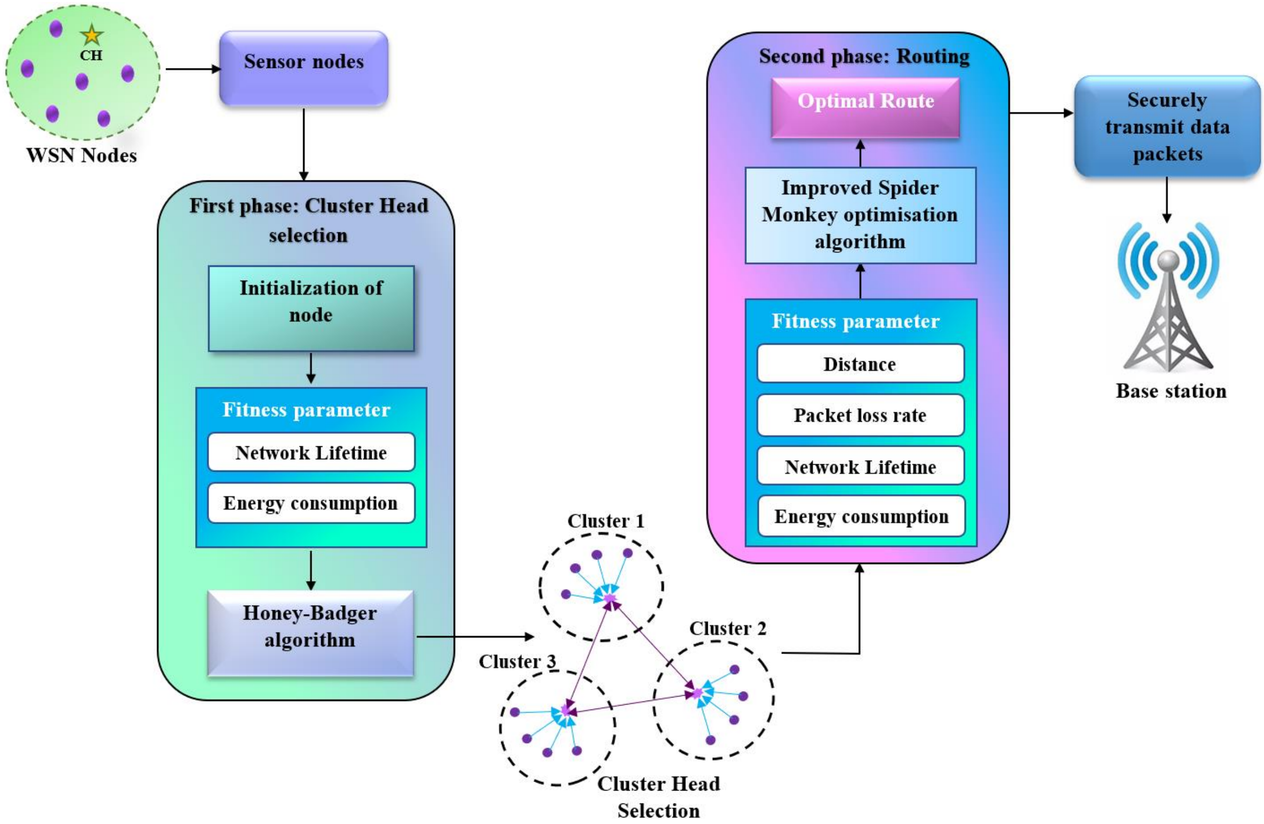

Figure. 1 The overall workflow of MEDIA-WSN Methodology

badger. In this phase, how does the honey badger effectively dig its prey, similarly the CH selection is effectively selected using the honey badger algorithm.

3.1.1. Initialization process

The first possible solution at this step is determined by the upper (Yu) and lower (Yl) borders of the problem space. As a result, according to Equation 1, the initial solutions consist of stochastic sets that can be produced by applying the following technique.

$$Y_a = Yl + R_1(1,d) \times (Yu - Yl), a = 1,2,3..n. \quad (1)$$

Where d represents the size of the solution, Y shows all possible solutions, and n solution suppliers are provided (honey badgers).

Updating positions: The candidates' Y_{new} coordinates have now been updated. For instance, this can entail employing a method that takes advantage of the honey stages or digging.

3.1.2. Digging phase

During this stage, the possible topics for search movements are controlled by the ability of the hunter's fragrance and the distance between the honey badger and the prey (F). Its motion is described by the following formula:

$$Y_{new} = F + Di \times \beta \times Min \times F + Di \times R_3 \times (F - Y_a) \times (\cos 2\pi R_4) \times (1 - \cos 2\pi R_5) \quad (2)$$

where β denotes the capacity of an insect to gather food. The intensity is In, and the R_3, R_4, and R_5 are uniformly distributed random factors having a range of 0 to 1 that were chosen at random. The Di, which acts as a search strategy indicator is created as follows:

$$Di = \begin{cases} 1 & if R_6 \le 0.5 \\ -1 & if\ else \end{cases} \quad (3)$$

3.1.3. Honey phase

Honey badgers use the honey phase to move about the honey lead bird when searching for beehives. The following equation was utilized to determine the honey phase:

$$Y_{new} = F + Di \times R_7 \times \sigma \times (F - Y_a) \quad (4)$$

where F is the top result so far and R_7 represents a number generated at random that ranges from 0 to 1.

Modeling intensity Min : The following calculation for every contender odor intensity Min of the prey is required then the honey badger's sense of insect odor regulates its activity.

$$Min = R_2 \times (Y_a - Y_{a+1})^2 / 4\pi(F - Y_a) \quad (5)$$

where F denotes the location of the prey and R_2 defines the random number between 0 and 1.

Density parameter modeling (σ): The sigma value controls the flow of information between the local and global search phases. As seen below, it is hypothesized that beta is represented during all iterations:

$$\sigma = C \times \exp\left(\frac{-r}{r_{max}}\right) \quad (6)$$

where r and r_{max} indicates the present iteration and the overall number of iterations. C denotes a constant whose suggested value is 2.

Escaping from local solutions: The search direction is indicated with a warning (Di), which was used by the algorithm creators to prevent getting stale on regional fixes.

3.2 improved spider monkey optimization (ISMO) algorithm for routing

SMOs are often population-based algorithms that draw inspiration from spider monkeys' social behaviour. SMO also includes a number of iterative phases, which are described in the next section.

3.2.1. Local leader phase

In the initial stages of this local leader phase, the existing swarm is updated. The present location of each spider monkey, the local leader's location, and the location of a randomly selected group member are used to establish a new trial location. The ($sm_{new}\ j$) generation of trial position is expressed in the Eq. (7).

$$sm_{new}j = \begin{cases} sm_{ij} + R(0,1) \times (ll_{kj} - sm_{ij}) + R(-1,1) \times \\ \quad (sm_{ij} - sm_{ij}), \quad if R(0,1) \geq pr \\ \quad sm_{ij}, \quad otherwise \end{cases} \quad (7)$$

Here, the position of the i^{th} spider monkey's coordinate j is expressed as sm_{ij}. The position of the local leading group k^{th} at coordinate j is expressed as ll_{kj} and the perturbation rate is defined as pr. If the generated position has better suitability than the current position, the new position is adopted.

3.2.2. Global leader phase

The only solutions updated at this stage of the global leader are randomly selected solutions. The calculation of probability for the spider monkey i is shown in Eq. (8). The distance between the people and their supply of food is used to calculate the fitness in this situation.

$$\text{Probability} = 0.9 \times \left(\frac{fitness_i}{MaxFitness}\right) + 0.1 \quad (8)$$

Furthermore, compare the suitability of the generated position and the current position to the better solution.

3.2.3. Global and local leader learning phase

The global leader in global leader learning will be updated as the spider monkey with the greatest fitness score. For each organisation, local leaders are chosen using approaches for developing local leaders.

3.2.4. Local and global leader learning phase

In order to update the local leader position up to a predetermined threshold, which is the local leader border, random initialization or merging of global and local leaders is taken into consideration during the local leader selection phase. On the other hand, if it is not updated for a given iteration, i.e. the global leader will be divided into more manageable groups at its maximum. All distinct groups will be combined into a single group if the location of the global leader is not changed and the maximum number of groups is generated in SMO.

3.2.5. Routing path identification using ISMO

If the position is not updated by the global optimum, the ISMO subgroups are combined into one group. In order to better the route selection process in the WSN, the ISMO attempts to balance the population diversity by applying three unique fitness parameters: energy, distance, and longevity. The routing area and sensor usefulness both affect how the SMO population is initially initialised. The clusters are then grouped using local leader and global leader factors. The increased cluster head value causes the GLP to adjust their position. This uses a greedy selection procedure to discover the CHs's best solution and keeps track of the CHs's present position. Then, to update the new position of CH, it is tagged with the new position and the global leader threshold limit count is applied. The CH is chosen using the results of the 100th iteration. Fig. 2

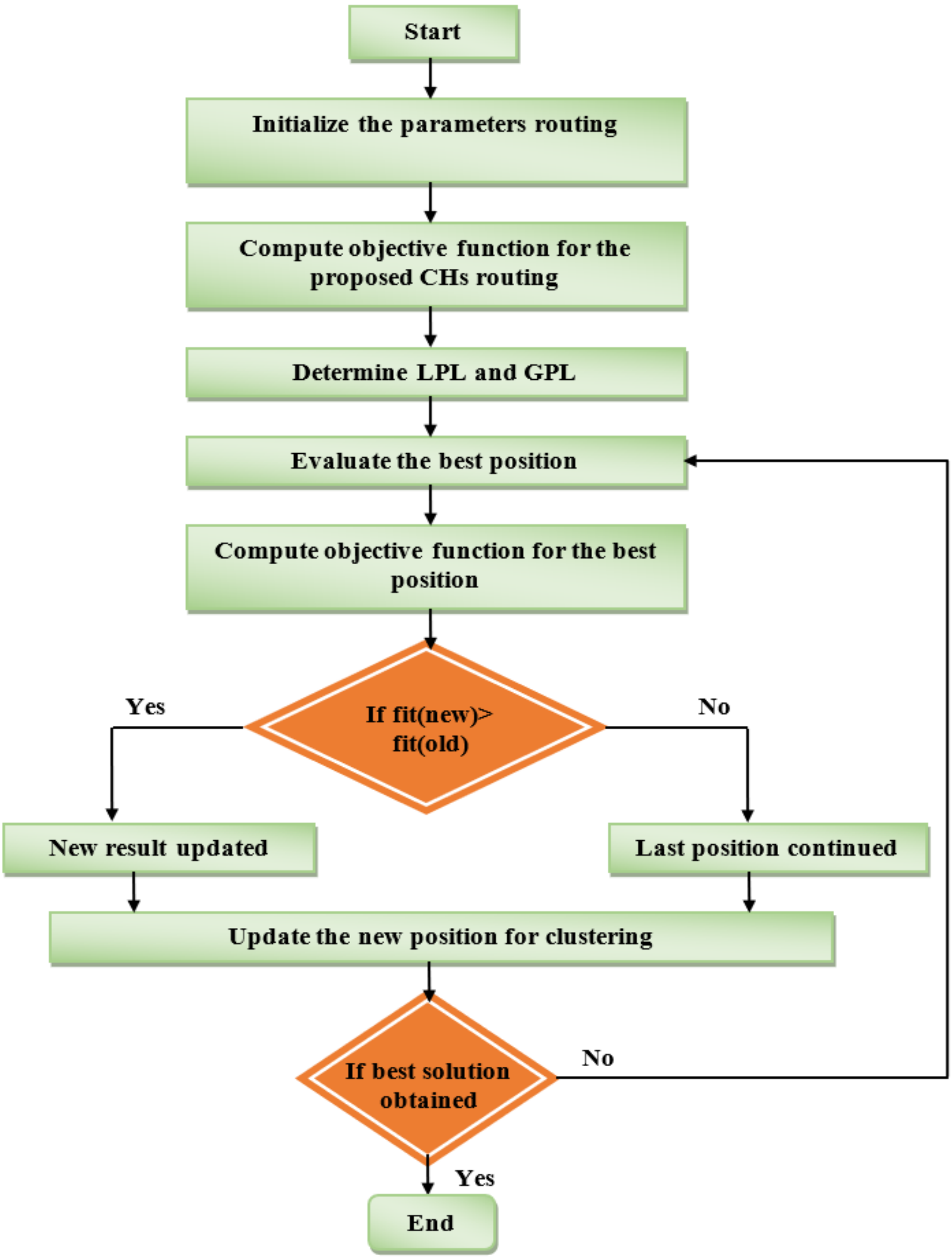

Figure. 2 Flowchart of Routing path identification using ISMO

Table 2. Simulation parameters of MEDIA-WSN

Parameters	Values
Nodes	500
Initial force	11.4J
Initial power received	0.486W
Initial power transmitted	0.720W
Size of area	500mx500m
Packet size	1024bytes

depicts, the flow chart for the SMO technique in CHs routing.

Because the sub-hubs are known to weigh less than the CH, the CH's function is modified to disperse the weight and increase the clusters' longevity. A node's energy consumption is reduced based on the distance and energy utilised in the fitness function. Particularly, the WSN's energy efficiency rises as a result of the ISMO's shortest path identification because less energy is used.

4. Result and discussion

The MATLAB framework is being used for executing the MEDIA-WSN methodology. In this experiment, a 60-metre square is the region of operation. Each sensor node has a 300m extended range for power transmission. The light-emitting on every node that senses emit the same amount of

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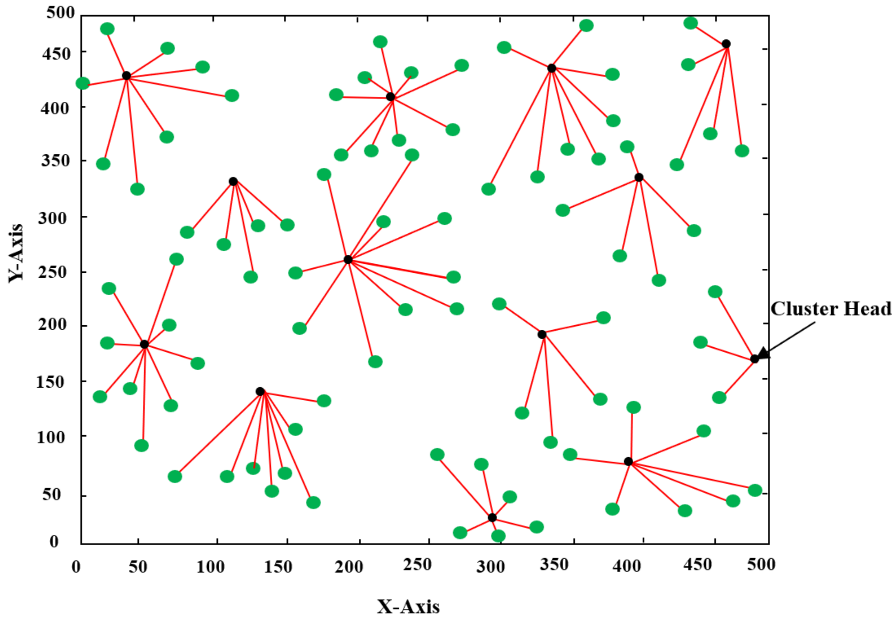

Figure. 3 Illustration of simulating result of cluster head formed in sensor network

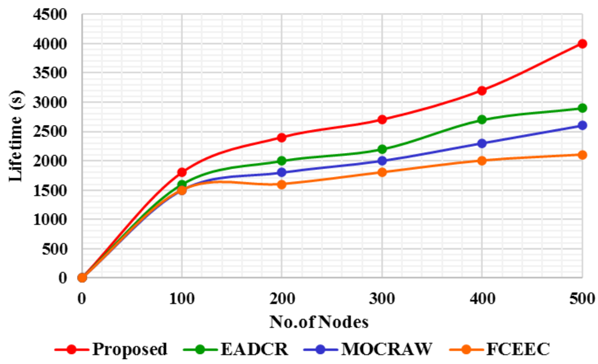

Figure. 4 Performance analysis of lifetime for the proposed MEDIA-WSN and Existing techniques

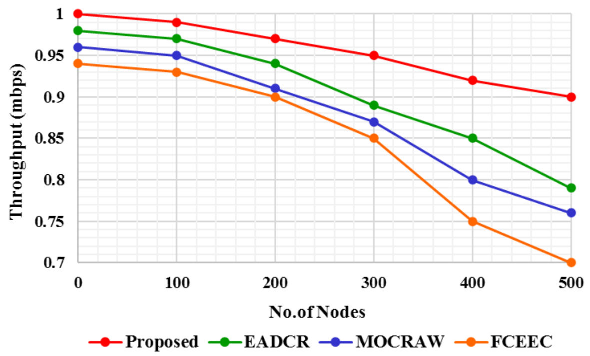

Figure. 5 Performance of throughput for the proposed MEDIA-WSN and Existing techniques

electromagnetic energy in every angle. Simulation Parameters for MEDIA-WSN method shown in Table 2.

There are 500 nodes in the network, which covers a total area of 500 x 500 metres. The data packet is 1024 bytes long, and the node's starting energy is 11.4 J. Thirteen clusters form within the network, which uses a mobile infrastructure.

Fig. 3 shows there were 500 communication rounds in all. The next stage after constructing the clusters is to select CH nodes and carry out source-to-destination data transfer. Additionally, it is believed that each chosen CH node has sufficient radio range to send data to the BS node directly without the need for an intermediary node.

4.1 Performance metrics

The MEDIA-WSN method performance was measured based on network lifetime, energy consumption, packet loss rate, distance, throughput. The effectiveness of the MEDIA-WSN method is measured by the following performance criteria.

Fig. 4 shows, the proposed MEDIA-WSN yields superior results when compared to EADCR [17], MOCRAW [18], and FCEEC [19]. In comparison to the current MEDIA-WSN has a longer lifespan. A number of nodes in the system rises, more nodes that collect data begin to distribute packets randomly, and there is a high likelihood that nodes will eventually pass away. The MEDIA-WSN approach only uses the best node to send data packets, extending the duration of the battery and the lifespan of the network.

Fig. 5 displays the results of the overall accomplishment for both recommended and current approaches. In terms of efficiency, the proposed MEDIA-WSN outperforms the existing techniques. The central station obtains additional information packets since MEDIA-WSN has a relatively long network lifespan.

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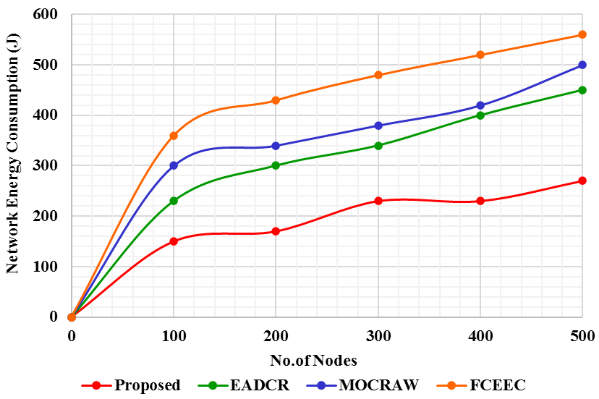

Figure. 6 Performance of energy consumption for the proposed MEDIA-WSN and Existing techniques

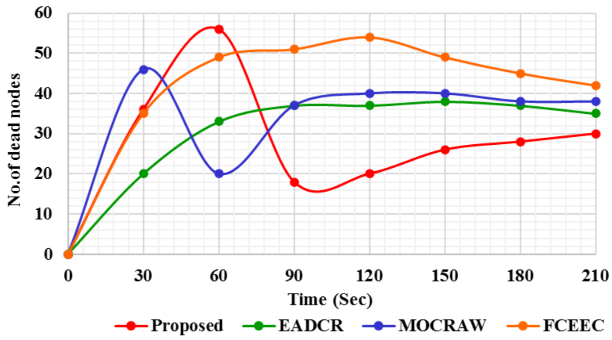

Figure.7 Representing the dead nodes during transmission

In Fig. 6 displays network energy consumption of MEDIA-WSN method. These variables are examined and compared to three currently used approaches, such as EADCR, MOCRAW, and FCEEC. According to their consistency, the MEDIA-WSN method keeps a sizable number of energy-efficient nodes for use in subsequent transmission by alternating between an active and sleep state.

As a result, the total amount of energy consumed is reduced because not all nodes are required to expend energy for an agreed transmission.

In Fig. 7 shows, the dead nodes during transmission. In proposed method, node transmitted in short time when compared to existing techniques.

In Fig. 8 end-to-end delay evaluation is carried out using existing methods. Performance of the machine as a whole improves when the delay charge is decreased. the proposed MEDIA-WSN framework set of rules has minimal latency, adding nodes to the WSN will result in an increase in latency.

Fig. 9 illustrates, the MEDIA-WSN achieves a small time and keeps trying to get the data packet to the most effective a link node, fulfilling its ideal feature. On the other hand, locating a terminating point node requires a lot of effort when using the conventional methods.

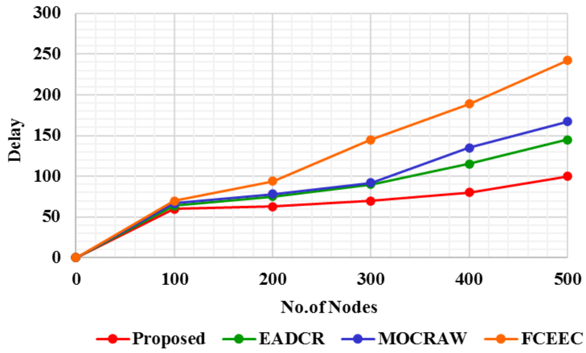

Figure. 8 Delay Vs Number of Nodes

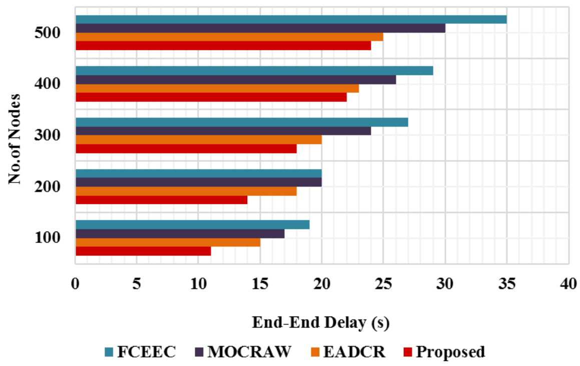

Figure. 9 Performance analysis of end-to-end delay for the MEDIA-WSN and existing techniques

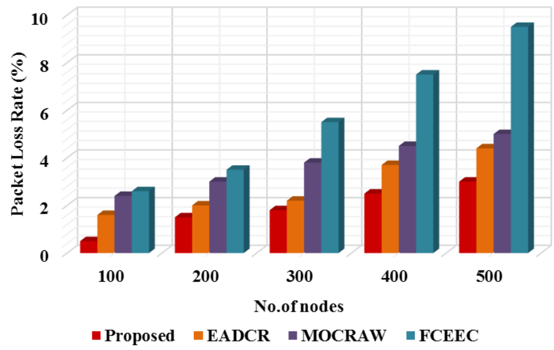

Figure. 10 Packet loss rate performance analysis for the proposed MEDIA-WSN and Existing techniques

Additionally, it starts the extended return from the end point node. As consequence, the common complete delay of the associated infrastructure is greater than that of the MEDIA-WSN method.

Fig. 10 shows, the MEDIA-WSN performance comparison of Packet loss rate. The MEDIA-WSN method creates superior outcomes when compared to current methods such as EADCR, MOCRAW, and FCEEC. Compared to the previously used current techniques, the MEDIA-WSN has a lower loss of packets rate.

5. Conclusion

This paper presents a novel multi-objective energy and distance integrated algorithm (MEDIA-WSN) based grouping and the distribution scheme that takes into account the key issues like heavy the lifespan of networks in WSN. The nodes that collect data are assigned to the connection close to the BS using the ISMO-based clustering, and a substantial number of detectors nodes are assigned to the connection away from the BS way. Additionally, the ISMO algorithm is used to determine the ideal route between the point of origin and the BS in order to improve network lifespan and energy consumption. The proposed MEDIA-WSN -based routing scheme performed better than the compared to current models. The result shows the MEDIA-WSN achieves higher performance in terms of energy consumption (0.45 J), packet delivery ratio (99.6%), packet loss rate (0.5%), and end-to-end delay (10 s), respectively. In future, a multi-hop routing technique with the aim of obtaining the high performance will be developed.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

The authors confirm contribution to the paper as follows: “conceptualization, M. Muthuselvi; methodology, M. Muthuselvi; software, M. Muthuselvi; validation, M. Muthuselvi; formal analysis, M. Muthuselvi; investigation, M. Muthuselvi; resources, M. Muthuselvi; data curation, M. Muthuselvi; writing—original draft preparation, M. Muthuselvi; writing—review and editing, M. Muthuselvi; visualization, M. Muthuselvi; supervision, M. Muthuselvi; project administration, M. Muthuselvi; funding acquisition, M. Muthuselvi, etc.

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