Nature Inspired Improved Firefly Algorithm for Node Clustering in WSNs

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Abstract: Wireless Sensor Networks (WSNs) comprises low power devices that are randomly distributed in a geographically isolated region. The energy consumption of nodes is an essential factor to be considered. Therefore, an improved energy management technique is designed in this investigation to reduce its consumption and to enhance the network's lifetime. This can be attained by balancing energy clusters using a meta-heuristic Firefly algorithm model for network communication. This improved technique is based on the cluster head selection technique with measurement of the tour length of fireflies. Time Division Multiple Access (TDMA) scheduler is also improved with the characteristics/behavior of fireflies and also executed. At last, the development approach shows the progression of the network lifetime, the total number of selected Cluster Heads (CH), the energy consumed by nodes, and the number of packets transmitted. This approach is compared with Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Low Energy Adaptive Clustering Hierarchy (LEAH) protocols. Simulation is performed in MATLAB with the numerical outcomes showing the efficiency of the proposed approach. The energy consumption of sensor nodes is reduced by about 50% and increases the lifetime of nodes by 78% more than AODV, DSR and LEACH protocols. The parameters such as cluster formation, end to end delay, percentage of nodes alive and packet delivery ratio, are also evaluated... The anticipated method shows better trade-off in contrast to existing techniques.

Keywords: Cluster head, wireless sensor network, LEAH, TDMA, firefly, AODV, DSR.

1 Introduction

Wireless Sensor Networks encompasses thousands of tiny devices that are able of transmitting/broadcasting sensed data to other nodes with limited power. The sensor nodes are deployed in a real-time scenario to observe diverse environmental changes. In general,

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nodes possess lesser power, therefore collected data from the targeted node is broadcasted to the Base Station (BS). It is also a node that receives data from Sensor Nodes (SNs). It examines data similarity between and makes an appropriate decision for data transmission. As well, the base station will not use these data locally; however, it transmits data to other networks. When this process is carried out, it leads to a huge overhead. The process of accumulating data from the entire sensors and establishing acknowledgment of a base station in the network connectivity is termed as data aggregation [Ali, Dey and Biswas (2008)]. WSN technology is utilized in various applications due to its adaptability to the environment. The following are the applications of WSN, such as survival monitoring, intelligent buildings, traffic control, military applications and object tracking [Adamou Abba Ari, Omer Yenke, Labraoui et al. (2016)]. Moreover, WSN suffers from some of the limitations as follows: reduced computation ability, limited battery power, limited memory, non-rechargeable, environmental setup, security, and global addressing. Energy balancing amongst sensor nodes is a major concern while implementing a sensor network. Energy consumption by nodes varies based on the application requirements. Sometimes SNs are deployed in a hostile environment where SNs will not be recharged.

Hence, batteries play a significant role in the sensor environment, i.e., lifetime of the node is determined using batteries. In a sensor network, energy-efficient routing protocols are required. Numerous investigations are carried out to design a sensor network to increase the energy efficiency of nodes. Various techniques have been in co-operated for saving nodes energy. These investigators initiate from the physical layer to the network layer through routing protocols to project how to enhance data acquisition techniques [Arumugam (2015)]. Along with this, clustering-based protocols [Batra (2016)] have graphed the attention of numerous investigators. It is composed of two phases: setup phase and the steady-state phase. In the setup phase, WSN is partitioned into clusters (node groups). In every sensor cluster, that operates as a cluster head (CH). In the steady-state phase, member of clusters will be attached to it (Non-CH nodes) which senses and broadcast its data to cluster head concurrently. Every sensor node takes its own time to sense and transmit data to cluster head. The sending process is based on Time Division schedules to transmit data, which is established by every cluster head and transmits it to all the members connected to the network.

The cluster head is accountable for reducing the sum of redundant data by applying the aggregation process; thereby it reduces the size of data and propagates it to BS. AODV, DSR and LEACH protocol are some of the leading protocol that is utilized by various network applications [Batra (2016)]. In this investigation, the work integrates energy-efficient cluster-based routing, schedule and meta-heuristic approach to get an optimal outcome. In the initial phase, nodes specify cluster heads that have been selected randomly after the sensor node deployment. A cluster head selection procedure is done randomly after node deployment. The selection process is performed at the beginning of every round. Random values are chosen by the nodes from 0 to 1. If random numbers are lesser than the selected Random Threshold Value (RTV) (n) that node will act as CH for the current round. RTV (n) is determined as in Eq. (1):

$$RTV\ (n) = \begin{Bmatrix} \frac{P_{CH}}{1-P_{CH}[mod(\frac{1}{P_{CH}})} & in \in N_{CH} \\ 0 & else \end{Bmatrix} \tag{1}$$

where,
P_{CH} is the percentage of elected cluster heads.
R is round to elect cluster head.
N_{CH} is a set of sensor nodes that are not selected as cluster heads in $\frac{1}{p_{CH}}$ rounds.
Even the existing protocols like AODV, DSR, and LEACH reduces energy consumption in sensor nodes and reduces routing table size. It exists some limitations like:

- When CHs are randomly chosen, residual energy will not be considered.
- When network size increases, CH's which is located more away from base station consumes more amount of energy quickly. DSR and LEACH protocol is modeled to work effectually in small deployment.
- Scheduler corresponds to transmission like TDMA has certain constraints. CH consumes its time frame to transmit data to its designated slot.
- Some of the generated clusters comprise of more SNs, whereas some clusters are affected by simultaneous transmission of data to BS. Nodes in some clusters will drain the energy rapidly than clusters with huge nodes.
- Nodes in the sensor clusters will generate a random number that ranges from 0 to 1. If the node number is lesser than the Random Threshold Value (RTV), it operates as a cluster head. Therefore, there are no limitations in constructing CHs. Cluster-based SNs encounter an energy efficiency problem when RTV value is higher than threshold value.
- The existing protocol considers that the nodes connected to cluster posse's equal energy efficiency to transmit/communicate with sink nodes. But, in general, more energy will be consumed when a sink is placed far away from BS.
- Existing protocols usually consider that the network will be homogeneous, but in general, networks may act either as homogeneous or heterogeneous.
- The above-mentioned protocols sometimes lack in privacy and security concern.

This work is organized as. Section 2 shows the description of existing protocols. Section 3 is an energy model with assumptions of the proposed approach is discussed in Section 4. The simulation results are in Section 5. Finally, the conclusion and future work are in Section 6.

2 Related works

This section discusses, in brief, the conventional approaches of energy management using optimization techniques and describes the advantages and disadvantages of the traditional approaches. LEACH is utilized as a baseline to cluster-based routing protocols. It spotlights randomized techniques to authorize cluster heads that die when the energy of CHs is consumed. The authorization technique is sourced on certain nodes that generally possess lesser residual energy to be utilized as cluster heads [Beiranvand, Patooghy and Fazeli (2013)]. Numerous research is carried out to accomplish energy balance inside wireless sensor networks.

Essentially, many protocols regulate network performance. Particularly, LEACH is a protocol associated with data transmission that is cast-off to gather cluster-based routing. Authors in Cai et al. [Cai, Duan, He et al. (2015)] anticipated that an energy routing protocol depends on effectual ensemble data and optimal cluster head selection. This protocol extends the network lifetime. However, it still suffers from delays produced due to multifaceted operations. It usually selects the sensor node that has higher residual energy devoid of considering other factors like sensor node location that locates far away from BS. In Elhabyan et al. [Elhabyan, Yagoub and PSO-HC (2014)] author anticipates an algorithm based on the random timer to generate a cluster without the requirement of any global information. This algorithm suffers from a gap in consuming energy between sensor nodes and cluster heads. More researchers investigate the placement of cluster head and nodes energy consumption issues.

Authors in Elhabyan et al. [Elhabyan and Yagoub (2015); Fister, Yang and Brest (2013); Gupta, Riordan and Sampalli (2005)] anticipated a protocol known as LEACH-B. The selection of the first cluster head is carried out by the original LEACH. However, initiating from subsequent selection, it alters the total number of cluster head sourced in nodes' residual energy. Therefore, numbers of clusters are fixed for every round and they are nearer to optimality.

Authors in Heinzelman [Heinzelman (2002)] initiated a technique for reducing EC by choosing SN like a cluster head based on the highest residual energy, total number of neighbors that are nearer to BS. Moreover, all algorithms in Hong [Hong (2008)] does not consider the presence of a smaller cluster. As well, the cluster head suffers from unexpected death and spotlights merely on EC by threshold and residual energy of nodes. In Hu et al. [Hu, Jin and Dou (2008)] the investigator proposed a co-operative communication technique.

Table 1: Comparison of existing clustering algorithms

	Packet Delivery Ratio	Data Aggregation	Energy Consumption	Network	Radio Model	Mult i-hop	Multi -path
LEACH-GA [17]	-	Yes	High	Homogeneous	First-order	no	yes
PSO-C [18]	average	yes	average	homogeneous	first order	no	no
PSO-HC [18]	-	-	average	homogeneous	CC2420	yes	-
TPSO-CR [19]	high	yes	average	homogeneous/ heterogeneous	CC2420	yes	yes
PSO-ECHS [20]	high	no	low	homogeneous	first order	-	-
T-ANT [21]	-	yes	average	homogeneous	first order	yes	-
EB AB [22]	low	-	average	homogeneous	first order	Yes	yes
ACO-C [23]	High	Yes	average	homogeneous	first order	No	yes
ACA-LEACH [24]	-	-	High	homogeneous	first order	yes	yes
MRP [25]	-	-	average	homogeneous	first order	Yes	yes

ABC-C [26]	High	-	average	homogeneous	first order	yes	yes
Bee-Sensor-C [27]	High	Yes	average	homogeneous	-	yes	yes
Bee Swarm [28]	High	Yes	average	homogeneous	-	Yes	yes
ABC-SD [29]	High	yes	low	homogeneous	CC2420	yes	yes
FCH [30]	-	no	high	homogeneous	first order	no	no
SEP-FL [31]	-	-	average	heterogeneous	First-order	-	-

Investigators in Karaboga et al. [Karaboga, Okdem and Ozturk (2012)] anticipated LEACH with cluster head selection techniques. Indeed, the algorithm attains energy distribution between all nodes; it does not measure the sensor nodes location factors that influence the selection of appropriate cluster head nodes. Authors in Liu et al. [Liu, Gao and Zhao (2012)] reduced EC and extend life through an approach termed as Variable Round LEACH. Moreover, this algorithm is based on residual energy at the initiation of data collision. Henceforth, this investigation enlarges the lifetime span by augmenting the SN cluster. The anticipated method is based on two improvement techniques. From the above-discussed approaches, various investigators attempted to overcome the EC of nodes and to manage optimal power consumption. This leads to a motivation to manage energy using a heuristic approach known as a firefly approach along with modification of TDMA schedule.

3 Equations and mathematical expressions

In Wireless sensor networks (WSNs), node deployment is measured as a fundamental crisis that influences numerous factors of network operations like security, routing, and energy. The lifetime of wireless sensor networks is based on node deployment techniques. Sensor nodes that are located nearer to the sink node (one hop away from the sink) will consume a higher amount of energy than the other nodes of the cluster [Zhou (2008)]. This is because it receives and re-transmits packets from and to other nodes. This leads to energy problems for the entire network. Therefore to overcome this issue, the location of sensor nodes and base stations are distinct using a two-dimensional Gaussian distribution function. The modeling of Gaussian distribution attains energy balancing and network lifetime improvement as the standard deviation factor has a significant role in both network lifetime and energy utilization. Assume a wireless sensor network model with N_sn sensor nodes and base station with random distribution R×R (m^2) simulation area. Here, the Gaussian distribution function is given as Eq. (2):

$$f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y}\exp-\left(\frac{(x-x_0)^2}{2\sigma_a^2}+\frac{(y-y_0)^2}{2\sigma_b^2}\right) \quad (2)$$

Based on the above Equation,

(x_0, y_0) specifies the position (location) of every node;
$\sigma_x and \sigma_y$ specifies the standard deviation for x and y dimensions correspondingly.

3.1 Sensor energy model

In this investigation, an energy radio hardware model is utilized [Ziyadi, Yasami and Abolhassani (2009)]. Two models are utilized for examination of EC, multipath fading model and free space model $\varepsilon_m d^4$ and $\varepsilon_f d^2$ respectively. These two models rely on distance amongst transmitter and receiver. The energy model of SN is given in Fig. 2. Therefore, transmit n- packet at distance d, radio use is provided as in Eqs. (3)-(5):

$$E_{TX(k,d)} = E_{TX-elec(k)} + E_{TX\,amp(k,d)} \tag{3}$$

$$E_{TX(k,d)} = \begin{cases} k * E_{elec} + k * \varepsilon_f * d^2, & d < d_0 \\ k * E_{elec} + k * \varepsilon_m * d^4, & d < d_0 \end{cases} \tag{4}$$

$$E_{RX\,(k)} = E_{RX\,-elec(k)} = k * E_{elec} \tag{5}$$

where,

E_{TX} specifies energy utilization for packet transmission.

E_{elec} specifies electronic energy that counts filtering, modulation of digital coding and signal spreading.

E_{RX} specifies energy utilization for receiving packets.

d_0 specifies square root of dividing EDA free space model using a multi-path fading model.

3.2 Optimal ch's

Consider that there are 'N' sensor nodes, with the clusters partition the network, that is, N=C average number of nodes per cluster. Cluster head energy consumption in a single frame is provided as in Eq. (6):

$$E_{CH} = kE_{elec} \,{}^{N}\!/_{C} + kE_{DA} \,{}^{N}\!/_{C} + K\varepsilon_m d_{BS}^4 \tag{6}$$

where,

E_{DA} specifies energy consumption of node aggregation

d_{BS} specifies the average distance from base station to cluster head nodes.

Energy consumption of normal nodes in the cluster for transmitting a packet to cluster is provided in Eqs. (7) and (8):

$$E_{normalnode} = kE_{elec} + k\varepsilon_f d_{CH}^2 \tag{7}$$

where,

$$d_{CH}^2 = \frac{M^2}{2\pi C} \tag{8}$$

$d_{CH}^2$is distance between the normal node in the cluster to cluster head nodes. The radius of network 'R' and area of every cluster is $\frac{M^2}{C}$.

$\frac{M^2}{C}$ specifies the cluster radius.

Therefore, total energy consumed by cluster in a single frame is provided as in Eq. (9):

$$E_{entirecluster} = E_{CH} + E_{non-CH} \frac{N}{C} \tag{9}$$

$$E_{cluster} = CE_{cluster} \tag{10}$$

By differentiating E_{total} concerning C to zero, the optimality of cluster head is attained as in Eq. (11):

$$k_{optimalcluster} = \frac{\sqrt{N * \varepsilon_f}}{\sqrt{2\pi}} \frac{1}{\varepsilon_m} \frac{M}{d_{BS}^2} \tag{11}$$

From the simulation, assume that all sensor nodes are distributed randomly over x and y coordinates between $(x = 0, y = 0)$ and $(x = 100, y = 100)$ and base station is located in (100-200), multi-path fading model is given as $\varepsilon_m d^4 = 0.0010 \frac{pJ}{bit} / m^4$ and free space model is given as $\varepsilon_f d^2 = 10\ pJ/bit\ /m^2$, based on these factors, expected number of cluster head relies from 1 to 7. Here, the C value is 6.
Level one headings for sections should be in bold and be flushed to the left. Level one heading should be numbered using Arabic numbers, such as 1, 2, …

Level two headings for subsections should be in bold-italic and be flushed to the left. Level two headings should be numbered after the level one heading. For example, the second level two heading under the third level one heading should be numbered as 3.2.

Level three headings should be in italic and be flushed to the left. Similarly, level three headings should be numbered after level two headings, such as 3.2.1, 3.2.2, etc.

4 Proposed methodology

This section explains in detail some of the drawbacks encountered in AODV, DSR and LEACH protocol. Three significant factors influence the performance of the above-mentioned protocols. Initially, inappropriate choice of cluster head amongst the sensor nodes. Next is the inequitable distribution of SNs in every cluster. Energy consumption in a smaller cluster is higher than that of a larger cluster. This is because smaller clusters usually transmit more amount of data than others in the cluster [Ziyadi, Yasami and Abolhassani (2009)]. Finally, the problem is associated with steady-state phase. The transmission was carried out if there is no appropriate updation of sensed data.

Along with this, three other problems are associated with the above-mentioned protocols and sudden drop in inefficient energy consumption. The sudden drop leads to a reduction of network lifetime. To overcome this problem, the anticipated technique presents two ideas to resolve the problem occurred in LEACH, DSR and AODV protocols. The proposed method attempts to reduce the sum of power consumed by sensor nodes. Cluster head selection is performed using a heuristic approach known as a firefly method that assists in enhancing the selection of cluster head and determines how to modify threshold T (n) to select appropriate cluster head nodes [Yu, Li, Yang et al. (2018)]. Along with this, every SN transmits its updated data only during its sending slot. It is not possible in permitting every SN to transmit data without updating. Moreover, sensor nodes inequality causes unbalance in energy consumption amongst cluster which is resolved by modifying the time-based scheduler that improves transmission.

4.1 Modified selection

To select a cluster head, this work considers the firefly algorithm with slight modification. Initially, the light intensity is a significant attribute that specifies the brightness of firefly. In the anticipated algorithm, a solution generated by every firefly comprises the permuted order of sensor nodes ID that has to be visited. Firefly intensity (I_F) depends on total tour distance in correspondence to a solution provided by firefly. Firefly intensity is provided in Equation given below (12) which is a fitness function. The primary objective is to reduce data gathering based on intensity and tour length with reciprocal of total tour length provided in Eq. (12). This leads to indirect proportion with other fireflies, that is, less tour length to have higher light intensity. The light intensity of firefly is computed as in Equation given below 12:

$$I_F = \frac{1}{distance(s(1), s(n_N)) + \sum_{i=1}^{n_N - 1} distance\ (s[i], s[i+1])} \tag{12}$$

These parameters comprise of residual energy of every sensor nodes, cluster heads are selected very frequently, the distance between the base station and cluster head, the average energy of sensor nodes in the current round.

Input: (1) Number of SNs in cluster; Sensor region: R×R; Light absorption coefficient: α; Updation Index:I_u; Total fireflies; Total generations.

Output: Optimal tour length (cluster range)

Step 1: Initialize parameters to sensor nodes, generation of tours, layout size, light absorption coefficient, and Updation index.

Step 2: Objective function initialization

Step 3: Construct a random population of fireflies with a corresponding tour

Step 4: Deploy SNs within layout size

Step 5: Evaluate distance amongst sensor nodes

Step 6: Compute intensity of fireflies using Eq. (12)

Step 7: While (iterations<No of iterations)

$\forall fireflies, m$ove firefly FF_i towards FF_i if $I_i < I_j$

Firefly attractiveness is varied with distance

Fireflies were constructed based on I_u

End

Choose fireflies that reflect the best tour to broadcast SN based on intensity as in Eq. (12)

End while

Step 8: Global best firefly provides the best solution

Step 9: Stop

4.2 Distance

For resolving the existing protocol problem, continuous optimization is involved. The distance amongst fireflies is easily evaluated with Euclidean distance which is used for optimization. However, the data gathering tour problem is a continuous optimization problem, therefore the Euclidean technique is not appropriate. Therefore, the distance between any two fireflies FF_1 and FF_2 is evaluated based on edges of nodes and the total number of sensor nodes deployed in it, as in Eq. (13):

$$\alpha_{\mathrm{FF}_1,\mathrm{FF}_2} = \frac{n_{edges}}{n_{sensor_{nodes}}} \tag{13}$$

where,

α_{FF_1, FF_2} is the distance between two nodes (firefly nodes), n_{edges} are edges of nodes and $n_{sensor\ nodes}$ specifies the number of SNs deployed in the network. Distance between nodes is provided as n_{edges}=3; $n_{sensor\ nodes}$=12. Therefore the distance is computed as 0.25.

4.3 Updation index

For obtaining an optimal solution, fireflies light intensity is determined. In general, fireflies with lesser brightness are attracted to firefly with higher brightness. This movement towards a higher bright firefly is performed using edged movement. Here, edges that are not in fireflies are evaluated and a random edge is selected. Then, edges are moved from missing edge till distance among two fireflies is reduced. By performing this, each firefly will offer 'k' optimal solution, in which, 'k' specifies the solution updation index. After the movement of all fireflies, the best firefly is constructed and selected for new population, i.e., cluster head selection for the next round. This process will be continued until the termination process is met. At last, the global best firefly attained provides optimal solution and it moves to visit all cluster nodes and colle1cts data from sensors in the minimum distance.

The number of neighbors of every sensor node has evaluated in the cluster head nodes selection stage. In Ziyadi et al. [Ziyadi, Yasami and Abolhassani (2009)], sensor nodes are determined as neighbors of sensor nodes are within the radius of the neighborhood of those nodes. Nodes with a higher amount of neighborhoods are considered to have higher chances to be elected as CH. The radius of the neighborhood is shown below in Eq. (14):

$$R_{FFneighbourhood} = \sqrt{\frac{M^2}{\pi * c}} \tag{14}$$

The average distance amongst CH and nodes is provided as in Eq. (14). The distance between CH and BS is given below in Eq. (15):

$$d_{sourcetoclusterhead} = \frac{M}{\sqrt{2 * \pi C}} \tag{15}$$

Another factor that is related to energy management is the lifetime of nodes in the network. T (n) is multiplied with factors that provide an energy level of sensor nodes. Firefly based computation provides modification in selecting the cluster head concerning edges of nodes.

This significant advantage of using fireflies is their intensity to travel to a specific region. Here, the network continues to transmit data to the neighbourhood when fireflies are attracted to it. This process is effectual when the brightness of fireflies is higher and if they locate very nearer to its neighbour. As the distance is higher multipath fading is encountered. E_{avg} increases when cluster head guarantees to transmit data to BS and until SNs are alive. Sensors possess higher residual energy than other nodes which is selected as CH node.

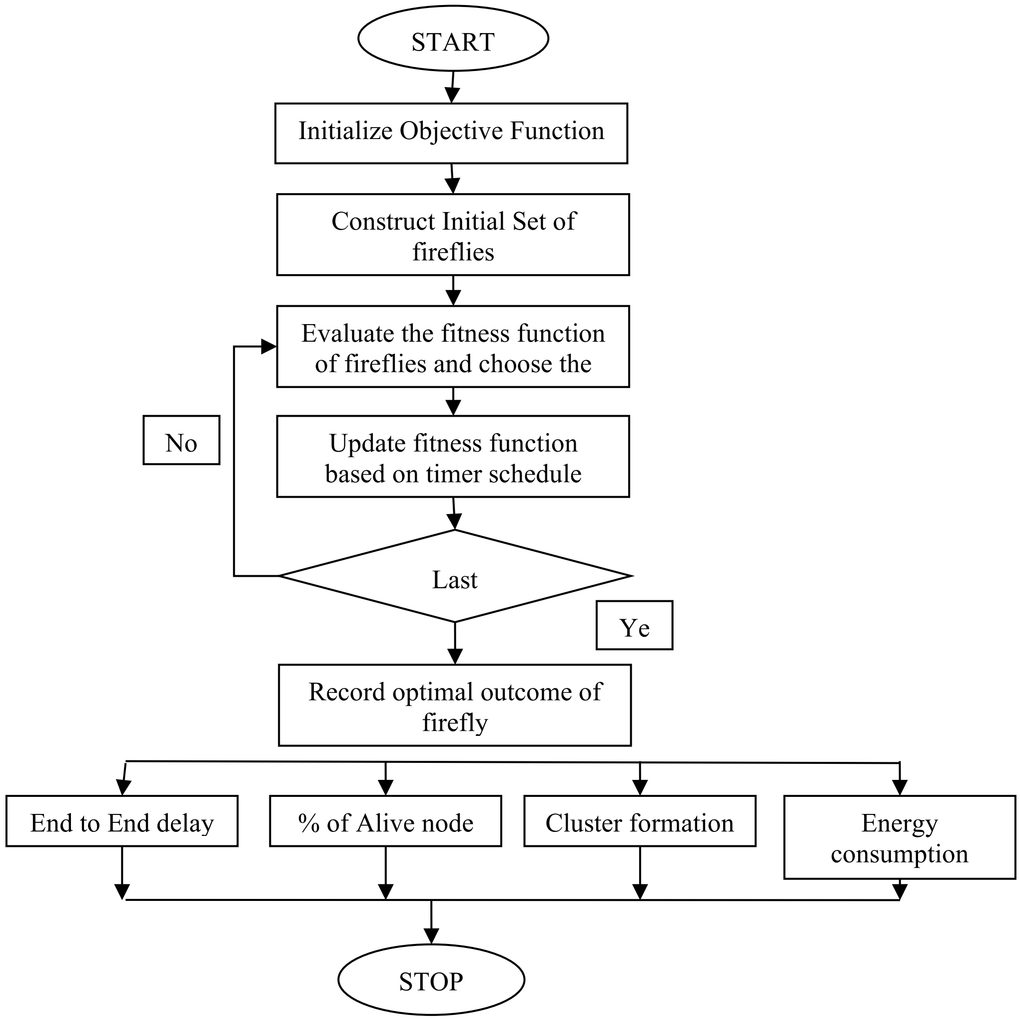

Figure 1: Flow diagram of proposed work

Distance between the fireflies affects the energy management problem. When the distance between the two fireflies is higher, it consumes a higher amount of energy for transmission to BS. Therefore, it is not advisable to select nodes away from BS as in Eq. (16):

$$T(n) = \begin{cases} T(n)(1 - \frac{1}{E_{avg}}) & in \in G \\ 0 & else \end{cases} \tag{16}$$

Thus, the selection of nodes includes the following operations:

- Sensor nodes will construct a random number between 0 and 1
- Compute threshold value attained from the formula given above.
- If random number is lesser than the threshold value, SN will act as CH node.

This formulates guarantees that sensor nodes with higher energy levels will possess higher chances to work as cluster heads in the current round. As well, it ensures that until sensor nodes are alive, data transferred to the base station. Moreover, as the distance of SN and BS is increased, CH selection in the current round is reduced.

4.4 Modified time-based scheduler

The anticipated technique attempts to overcome the disadvantages of AODV, DSR and LEACH protocol by minimizing energy between sensors in every cluster. Therefore, when cluster head selection is carried out, every cluster head transmits an acknowledgment message to declare itself as a cluster head node. Concerning the acknowledgment message, every sensor nodes attain this message will respond to those request to connect to the cluster head. Therefore, every cluster head identifies the number of sensor nodes that joins the cluster. There are various amounts of sensor nodes that merge to every cluster. Steady-state is partitioned into frames; where every node comes to a cluster transmit its data as per frame during its slot time. Cluster head awake to receive data from nodes in a cluster. Timeline operation of a steady state is higher than the setup phase. Therefore, a modified scheduler is an anticipated approach in four steps to resolve this crisis.

Step 1: Every CH evaluates number of SNs allocated to cluster sourced on number of receiving requests.

Step 2: Every CH will transmit message comprises number of own nodes merged with CHs. Finally, every cluster head recognizes its cluster capacity.

Step 3: The largest cluster capacity is determined to analyze time-based scheduling in clusters during the steady-state phase.

Step 4: Every node in the cluster can broadcast data based on the scheduler in steady-state phase. Therefore, every node transmits similar data amounts to its CHs. Therefore, nodes drain similar amount of energy. Cluster with fewer nodes after transmitting data in steady-state phase, else it will move to sleep mode. It as well avoids nodes to move to an idle state that in general affects nodes energy level.

The major difference between anticipated fireflies and the existing AODV, DSR and LEACH protocol can be modified using examples given below. Assume 25 nodes from 5 clusters for the first round. The nodes in cluster possess unique ID from 1 to 25. TDMA is the timer schedule utilized for 5 clusters in the firefly approach.

Consider sensor nodes that consume 'x' secs to transmit data to CH. In composed cluster, the transmission may occur randomly to nodes in the cluster. It specifies that data can be transmitted only once in a cluster for an initial round in CH. On the contrary, the cluster may possess a limited amount of nodes for every round in cluster. Therefore, energy consumed by nodes 10 to 17 is consumed more in the cluster node.

Moreover, by the anticipated technique, every cluster head transmits modified TDMA schedules to remaining nodes in cluster. Therefore, every SN recognizes its allocated time slot to transmit data to its corresponding CH [Ziyadi, Yasami and Abolhassani (2009)]. As well, every SN determines when it to switch off the radio model and moves to sleep mode. In a cluster, node 1 transmits data to node 15 and sends data in steady-state phase. No SN will transmit data to another network. Improvement attains balance to overcome SN inequality. However, it shelters SNs' energy from inappropriate consumption.

5 Simulation setup

The anticipated technique is simulated with MATLAB 2015. The Gaussian distribution is executed using the MATLAB environment. Wireless sensor networks are represented with 100 SNs deployed in 100 × 100 m^2. BS is placed in (40, 200). The initial energy consumed by nodes is 5J. The simulation of the anticipated technique runs at an average of 20 times. The simulated outcomes of the proposed method are compared with measured outcomes of AODV, DSR and LEACH protocol. A comparison of measured outcomes with other protocols is carried out based on performance metrics that comprise of a lifetime, number of CHs, and the number of received packets for measuring energy at BS and energy dissipation. Simulation factors are given below as in Tabs. 2 and 3.

Table 2: Simulation setup

Parameter	Value
Layout region	100 × 100 m^2
Location of BS	(0, 0)
Number of SNs	50-500
Transmission region	30-50 m
Deployment	Random

Table 3: Fireflies parameter and a corresponding value

Parameter	Value
Total number of fireflies	50
Total generations	500-750
α	0.02
k	4

5.1 Modified time-based scheduler

The total number of CHs extremely influences the energy efficiency of WSNs. When the total amount of CH increases, energies are extremely consumed by nodes owing to its huge amount of aggregation process carried out by cluster heads. Subsequently, when the total amount of CHs are reduced, energies are consumed extremely owing to its huge amount of aggregated data by every CH node and longer period, every CH requires to communicate with BS to report bulk data. Therefore, CHs will drain in the previous stage.

Therefore in successive rounds, cluster head stability of nodes in the cluster around an optimal amount of number is essential to attain balanced energy consumption. Fig. 2 shows the total amount of clusters in each round in contrast to LEACH, AODV and DSR protocols. The experimentation demonstrates that the optimal amount of cluster head is approximately about 6 as an optimal amount to achieve better recital than other numbers. This enhancement is sourced in a modification in the selection of a cluster head algorithm which also enlarges several rounds.

Tab. 4 illustrates a comparison between the AODV, DSR, and LEACH with the proposed method in successive rounds. The proposed methods attain stability to optimal number of CH equal to 6 owing to distribute energy consumption over the entire sensor nodes by partitioning cluster heads over its members.

Table 4: Clustering BS inside the network

Number of the cluster formed				
Nodes	LEACH	AODV	DSR	Firefly
75	9	10	10	11
150	13	14	15	15
225	21	24	23	25
275	25	24	25	26
350	26	25	27	26
400	29	31	33	32

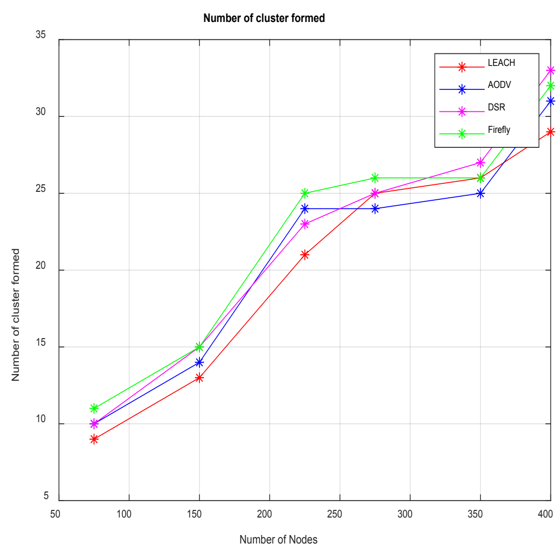

Figure 2: Cluster formation inside network

Table 5: Clustering BS outside the network

Number of the cluster formed				
Nodes	LEACH	AODV	DSR	Firefly
75	10	11	11	12
150	14	15	16	14
225	22	25	24	26
275	26	25	26	27
350	27	26	28	27
400	30	32	34	33

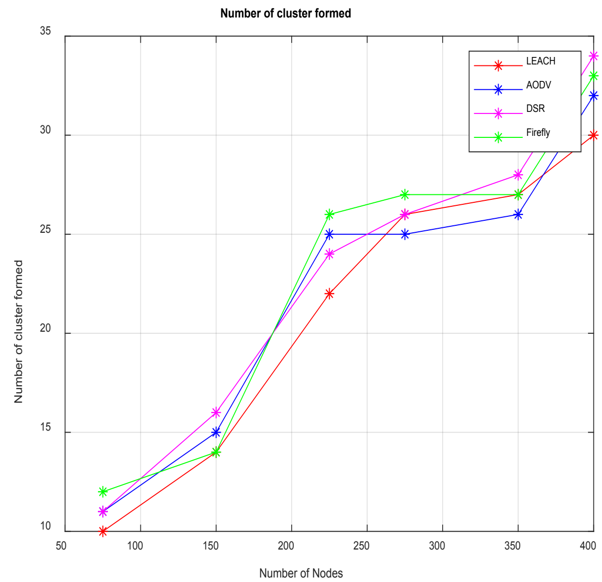

Figure 3: Clustering BS outside the network

From Tab. 5 and Figs. 2 and 3 specifies the number of clusters constructed (inside and outside) using the Proposed Firefly based clustering algorithm works better than LEACH, AODV, and DSR algorithm. Results show that the proposed Firefly based clustering algorithm performs better by 9.3% than LEACH, by 5.32% than AODV and by 1.49% than DSR in terms of cluster formation.

Table 6: Average E2E delay inside the cluster

Average E2E delay				
Nodes	LEACH	AODV	DSR	Firefly
75	0.0011	0.0011	0.0012	0.001
150	0.0012	0.0015	0.0012	0.001
225	0.0116	0.013	0.0122	0.0118
275	0.0197	0.0159	0.0195	0.0195
350	0.0404	0.0361	0.043	0.0431
400	0.0436	0.04	0.045	0.0435

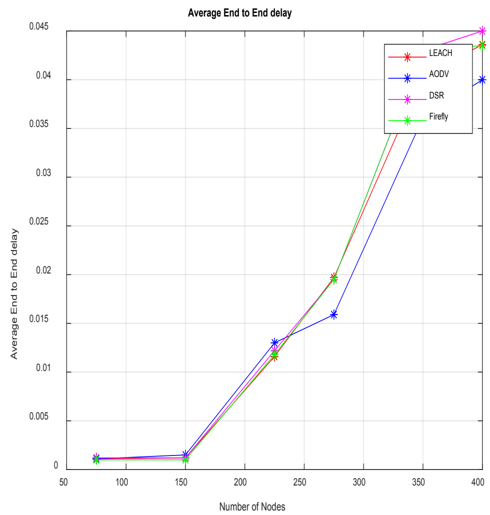

Figure 4: Average E2E delay inside the network

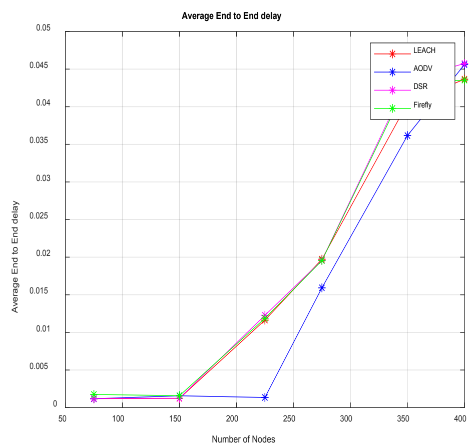

Figure 5: Average E2E delay outside network

Table 7: Average E2E delay outside the cluster

Average E2E delay				
Nodes	LEACH	AODV	DSR	Firefly
75	0.001182	0.001178	0.001221	0.00175
150	0.001222	0.001574	0.001245	0.00158
225	0.011631	0.001345	0.012265	0.011875
275	0.019725	0.015925	0.019578	0.019541
350	0.040441	0.036165	0.04356	0.043136
400	0.043665	0.0456	0.04575	0.043527

Tabs. 6 and 7 and Figs. 4 and 5 it is observed that E2E delay (inside and outside) of the Proposed Firefly based clustering algorithm is lower than LEACH, DSR, and AODV based clustering algorithm. Results show that the proposed Firefly based clustering algorithm performs lowers average delay by 1.49% than LEACH, by 10.31% than AODV and by 3.29% than DSR.

5.2 Network lifetime

It is defined as the maximum amount of time between last and first node death. The stability period should be higher for networks which is an essential factor as the loss will affect outcomes. Fig. 6 demonstrates a lifetime of AODV, DSR LEACH protocols and Firefly based TDMA scheduler. It is noticed that the anticipated approach enhances first node death in round 15 as compared to LEACH in round 5, AODV in round 11 and DSR in round 14. In round 16 LEACH loses 9 sensor nodes, AODV loses 4 nodes and DSR loses 1 sensor nodes. Therefore, a significant enhancement instability period is attained, which is needed for some applications. Tab. 8 shows the comparison among the above-mentioned protocols in diverse rounds 15, 25 and 30.

Table 8: PNA inside cluster

Percentage Node Alive				
Rounds	LEACH	AODV	DSR	Firefly
0	100	100	100	100
100	100	100	100	100
200	90	95	99.5	100
300	70	86	92	96
400	40	72	77	84
500	15	52	62	62
600	0	0	18	32
700	0	0	0	12
800	0	0	0	0

Table 9: Residual energy inside the cluster

Residual Energy				
Rounds	LEACH	AODV	DSR	Firefly
0	0.6	0.6	0.6	0.6
100	0.45	0.5	0.48	0.47
200	0.25	0.35	0.38	0.44
300	0.3	0.3	0.35	0.42
400	0.2	0.3	0.35	0.39
500	0.14	0.2	0.3	0.32
600	0	0.2	0.25	0.3
700	0	0	0.1	0.13
800	0	0	0	0

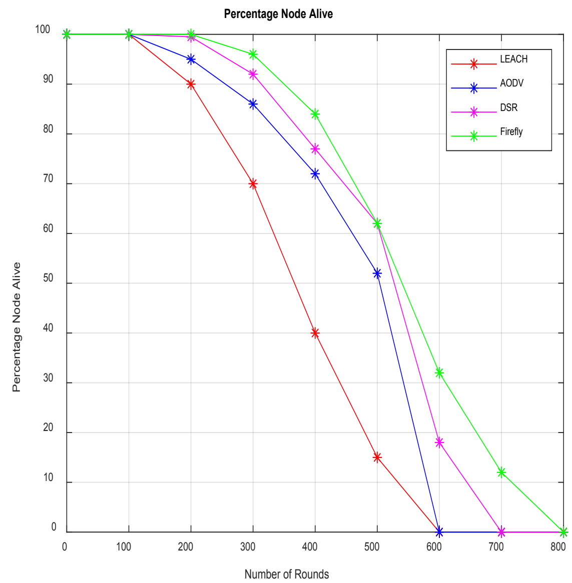

Figure 6: Percentage of an alive node outside the network

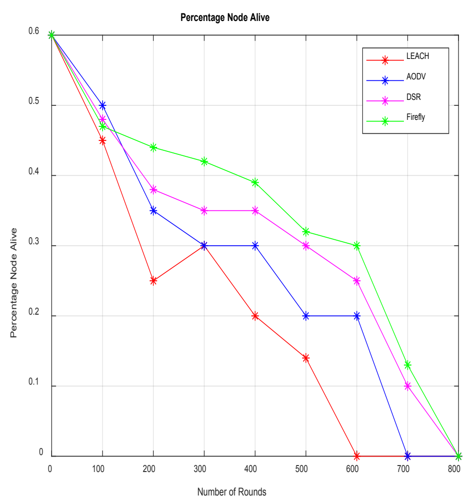

Figure 7: Percentage of the alive node inside the network

From Tab. 9 and Fig. 7 specifies nodes alive % of Firefly based clustering algorithm performs better than LEACH, AODV and DSR algorithm. Results show that the proposed Firefly based clustering algorithm performs better by 31.09% than LEACH, by 14.32% than AODV and by 6.45% than DSR.

5.3 Total packets in BS

Here, total packets received at BS are higher than existing approaches as illustrated in Fig. 8. The estimated amount of packets estimated for Energy Consumption (EC) is more stable that is, a huge amount of packets at BS. This improvement is attained using the CH selection technique, which guarantees balanced construction of CHs between all clusters. Energy balance leads to CH stability which leads to nominal energy dissipation.

Table 10: Average PDR inside the cluster

Average Packet loss rate %				
Nodes	LEACH	AODV	DSR	Firefly
75	8.5	7.5	6.9	7.5
150	12.75	11.5	10.5	9.12
225	13.2	12.5	10.75	9.5
275	18.5	17.1	15.75	14.53
350	25.68	23.15	21.3	20.15
400	35.48	32.8	25.1	23.05

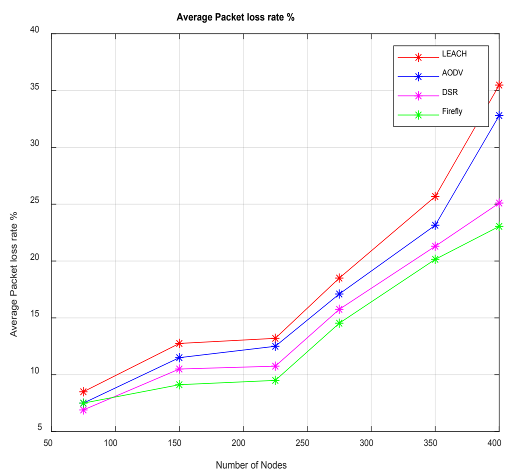

Figure 8: Average packet loss rate % outside network

Table 11: Average PDR outside the cluster

Average Packet loss rate %				
Nodes	LEACH	AODV	DSR	Firefly
75	8.6	7.7	7	7.36
150	12.8	11.7	11	9.12
225	14.3	12.7	11	10.73
275	19	17.3	16.5	16.25
350	27.62	23.7	22.3	22.5
400	36.48	33	25.9	25.5

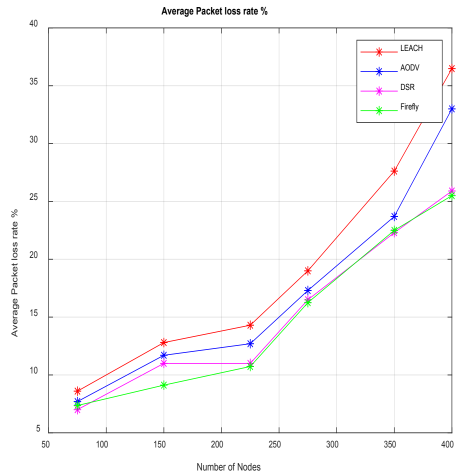

Figure 9: Average packet loss rate % inside the network

Another cause for this enhancement is due to modified TDMA which guarantees that SNs approximates the same energy for transmitting the same data as in Fig. 9. A huge regularity of energy consumption specifies huge amount of packets received in the base station as in Tabs. 10 and 11.

5.4 Energy consumption (EC)

EC specifies total energy utilized to carry out reception, aggregation, and transmission. Comparison is carried out amongst various approaches sourced in energy consumption in both cluster members and CHs of sensor nodes. In both cases, the total amount of nodes equal to 50, 100 and 150 nodes. Fig. 10. The anticipated firefly approach attains minimum EC in contrast to existing techniques like AODV, LEACH, and DSR. As well, improvements in energy consumption are fulfilled on cluster members and cluster head. This enhancement is attained based in sleep mode and switch off mode allocated to every sensor nodes after transmission and appropriate cluster head selection mentioned above.

Table 12: Percentage of an alive node outside the cluster

Percentage of alive node				
Number of nodes	LEACH	AODV	DSR	Firefly
0	100	100	100	100
100	98	98.8	98.95	98.28
200	96	97.2	97.26	95.56
300	0	94.3	94.39	87.7
400	73	80.99	80.96	71.94
500	60	59.37	59.36	55.03
600	15	29.89	29.87	7.05
700	0	10	9.98	0
800	0	2.58	2.14	0

From Tab. 12 it is observed that Percentage nodes alive for Multi-hop Firefly based clustering performs better than LEACH, AODV, and DSR. Results show that the Multi-hop firefly performs better by 3.97% than LEACH, and by 10.91% than AODV clustering. At last, sleep mode and switch off mode preserves sensor node from the cluster head and inefficient transmission from the idle stage. Tab. 12 demonstrates energy consumption and alive time of both nodes in the proposed and the existing LEACH, DSR, and AODV protocols.

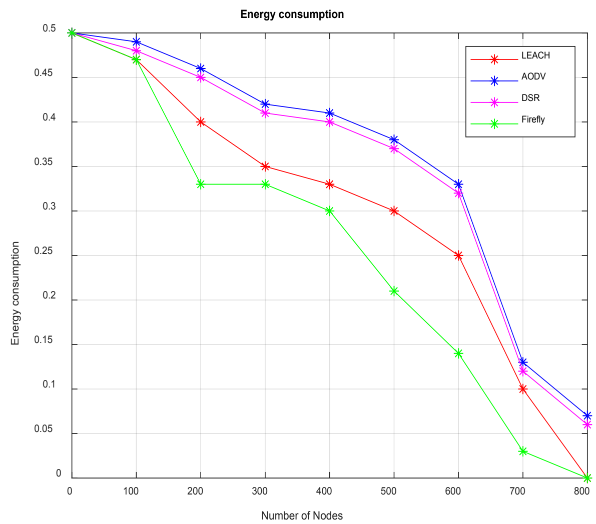

Figure 10: Energy consumption of nodes

Table 13: Energy consumption of nodes

Energy consumption				
Number of nodes	LEACH	AODV	DSR	Firefly
0	0.5	0.5	0.5	0.5
100	0.47	0.49	0.48	0.47
200	0.4	0.46	0.45	0.33
300	0.35	0.42	0.41	0.33
0	0.5	0.5	0.5	0.5
400	0.33	0.41	0.4	0.3
500	0.3	0.38	0.37	0.21
600	0.25	0.33	0.32	0.14
700	0.1	0.13	0.12	0.03
800	0	0.07	0.06	0

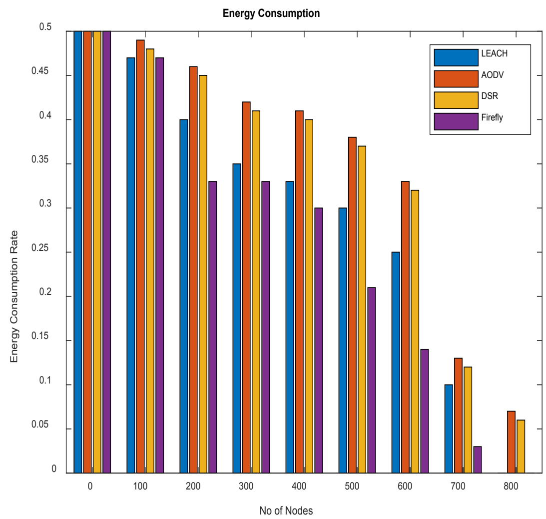

Figure 11: Energy consumption of nodes based on existing *vs.* proposed

From Tab. 13 and Fig. 11 it is observed that the remaining energy computation for the FireFly based clustering algorithm performs better than LEACH, AODV, DSR algorithm, and GA. Results show that FireFly based clustering algorithm performs better by 52.77% than LEACH, by 29.83% than AODV, by 13.88% than the DSR algorithm.

6 Conclusion and future works

An effectual methodology to improve routing with the firefly algorithm has been applied. Two techniques have been provided. Initially, this approach attempts to choose appropriate cluster head node for every cluster at each round. It is performed by differentiating the CH election process. The subsequent approach has aimed to eliminate the process of transmitting huge data packets. This issue is eliminated by TDMA rescheduling for every sensor nodes using corresponding CH to balance entire nodes in cluster to transmit the same amount of data. In this technique, a radio model based on the firefly algorithm is designed. This model facilitates the computation of distance measure of nodes from BS to recognize optimality of reducing energy consumption, thus TDMA is rescheduled at every node to make the firefly work effectually and to reduce the tour time. The proposed idea reduces the distance amongst nodes and reduced the energy consumption of nodes which is a significant factor. Based on time rescheduling tour length is reduced in sensor network applications, thus preventing data redundancy is multi-hop neighbors. This diminishes distance traveled by nodes in cluster and improves network performance. From the above-mentioned procedures, two works have been anticipated that improve lifetime and power consumption in WSNs. Therefore, lifetime is improved in contrast to LEACH, DSR and AODV protocols. The implementation outcomes of the anticipated approach have been verified using MATLAB 2015 simulation. With this execution, the anticipated approach has been compared with existing protocols concerning the number of cluster head, energy consumption, network lifetime and total packets transferred to BS which attains superior outcomes than other approaches.

In the future, the proposed approach will also be attempted in a heterogeneous environment.

This work focuses on energy consumption and the method to balance it. But does not specify security and data privacy to wireless sensor networks, therefore this work is extended to security concepts.

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