Energy Effective Data Gathering In Wsn: A Hybrid Approach Using K-Means And AFSO

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Abstract: Data gathering using a static sink causes the nodes nearby sink to run out of energy very soon and isolate the network. The invention of Mobile Sinks has reduced energy consumption, balanced the network by even energy consumption, and also solve hotspot issues by keeping the network connected. But all these are dependent on the mobile sink path. In this work, a dual mobile base station data gathering, and mobile charging path is formed by the artificial fish swarm optimization algorithm. The path is formed considering fitness function. The data gathering points known as summit stations are formed by using the K-means algorithm by calculating the weight function establishing complete coverage of all the nodes. The proposed method EEDG is vindicated with existing algorithms in terms of packet delivery ratio, delay, lifetime, and goodput. Results Show increased packet delivery ratio and reduced delay when compared with existing algorithms. EEDG prolongs the lifetime by 52% more than K-means and 78% more than GEACH.

Keywords: Data Gathering, Energy Replenishment, Fish Swarm Optimization, Optimal Path, Wireless Sensor Network

1. Introduction

Wireless sensor networks have potential in many fields because of their reasonable cost, size and convenience to be placed in the network region, such as developed cyber-natural conditions, active cities, to observe industrial and home applications, unknown environmental and object tracking system, deep water investigations, and so on. This kind of network requires a specific path selection to pass on data packets to the base station with minimal delay. In such condition, it should not fail because of its energy loss. Many studies have provided results to boost energy in the sensor networks, including situational energy harvesting systems, which pointed to the compilation of natural energy from the energy sources by nodes. The evolution of wireless energy supply technologies created stable energy transfer to nodes in sensor networks.

The artificial fish swarm algorithm is inspired by the actions of fish. AFSO gives better-optimized results when compared to other swarm algorithms(Neshat et al. 2012).

In the proposed work, the network is established with a group of sensors and then sensors transmit data packets through the mobile base station to the destination. The base station establishes data collecting point of the mobile base station using k means computations and the mobile base station movement path is set up by artificial fish swarm optimization to get an optimized path to gather data. Also, sensors can renew their power through mobile power suppliers.

Contributions:

- Most of the existing works don't consider mobile sink and mobile charger together which when combined enhance network lifetime.
- The path of the mobile base station is formed by artificial fish-swarm algorithm which ensures high accuracy.
- One hop distance between Summit stations and nodes is considered. Each SN only requires storing its data. Hence reduces overhead and energy consumption of sensor nodes due to minimum distance.

To form the summit stations one-hop neighbours, distance and mean hop distance are considered which will reduce the delay and time for transmission by forming an optimal path for the mobile base station.

2. Related Works

The wireless sensor nodes in the network are capable of sensing, computation, and communication. Sensor nodes are known as Micro Electro Mechanical System (MEMS) that sense a measurable amount of reaction to a general change in physical characteristics like temperature, humidity(Rajkumar, Monica, and

Sekar 2019). The information sensed is dispatched to the base station. But these sensors have a short battery so there is a need for effective protocols. A cluster-based routing protocol is considered the best type of routing protocol in energy-saving for sensors and prolonging the network lifetime. Each cluster has member nodes called ordinary nodes (ON) and a special node called cluster head (CH)(Hassan et al. 2019). In (Dash et al. 2015)and (Purushothaman and Saminadan 2014)the authors use tree-based routing to balance the energy consumption in nodes.

The conduct of ants, bee colony, bacteria foraging have been noticed as properties of distributed systems and can be modeled as a multiagent system. And can be applied to a variety of networking applications like wireless sensor networks(Krömer and Musilek, n.d.).In (Rao, Jana, and Banka 2017) Particle Swarm optimization-based clustering approach called PSO-ECHS is proposed. Residual energy, inter-cluster, and sink distance are considered. The nodes join CH by a weight function.

A clustering algorithm using a genetic algorithm is proposed in (Baranidharan and Santhi 2015). It increases the life of the nodes and makes the network stable. The fitness function in the algorithm improves the first, half, and last node dead.

AFSA (artificial fish-swarm algorithm) is the finest optimization algorithm amongst the swarm intelligence algorithms. This algorithm is inspired by the combined movement of the fish and their varied communal behaviours. (Neshat et al. 2012). In(Helmy, Ahmed, and Hassenian 2015) The cluster head is chosen by the Artificial Fish Swarm method. The behaviours of fish are used to select the finest cluster head. Fitness is used to analyse behaviour selection. This technique improves the life span for individual nodes and even the entire network.

The traffic near the base station in a wireless sensor network causes the closer sensors to exhaust energy faster than the remaining nodes, causing breakage of communication. To solve these mobile sinks are introduced. They balance the network and help in uniform energy consumption(Tunca et al. 2014). Many existing works have introduced mobile sinks for data collection(Altınel and Ersoy 2010). The mobile sink can be divided as direct where sink visits each node which increases energy consumption but minimizes delay and rendezvous, here sink visits only the data gathering points(Salarian, Chin, and Naghdy 2014). In(Xing et al. 2008), A RD-VT algorithm is used to form the path of the mobile sink. Steiner minimum tree is formed and is traversed in pre-order for selection of RP's which will cause lengthy forwarding paths to the nodes in other parts of the tree.In(Saad, Awadalla, and Darwish 2009) a moving path for mobile sink for hierarchical networks is presented. This removes multi-hop relays and reduces energy loss through them. It outperforms static sink strategy, periphery strategy, SenCar, and HUMS. To reduce overhead for path formation and maintenance by the mobile sink, data-driven routing, and random walk routing is implemented in (León, Hernández-Serrano, and Soriano 2010)

Researchers focused on harvesting energy from the environment to energize the sensor nodes. This method can extend the life of WSNs, and even make sensor nodes run for long. A different network protocol is required for EHWSN. Energy potential function is added to LEACH protocol to measure sensors replenishing capacity, it will help in improvising the throughput(Xiao, Zhang, and Dong 2013). Cluster algorithm for homogeneous WSN is proposed. THE Solar EH node is taken as a relay node and there is an enhancement in a lifetime(Zhang, Xiao, and Tan 2011).

But drawing out energy from the environment remains restricted. As the result of harvesting is completely dependent on the environment. As in a solar harvesting system, harvesting depends on time and exposure to the sun. (Guo, Wang, and Yang 2014) . Latter research in radio frequency (RF)- based wireless power recharge will extend the lifetime of WSNs. Wireless charging will not be affected by the changes in the environment and will not affect the functioning of the sensor.

3. EEDG Design and Implementation

3.1 Network Model

The network consists of sensors, mobile base stations M_{BS}, mobile power suppliers M_{PC}, and a static base station B_S(Fig 1). Sensors are randomly dispersed in the field and the base station leads the network. It circulates the B_S advertisement message consisting of its location to the whole network. Sensors throughout the network listen to B_S advertisement messages and respond by sending their location and periodical energy reports as a response to the B_S advertisement message. The sensor information will be collected by the base station at beginning of each round.

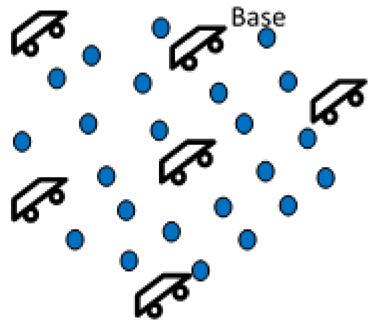

Figure 1. Network with sensors and mobile base stations.

The B_S forms Summit station terminal (S_S) by modified K-means calculation (Kaswan, Nitesh, and Jana 2017)to streamline mobile base station (M_{BS}) route as shown in fig 2. The S_S terminal-based M_{BS} movement route selection has relieved the complexity of lengthier passage of M_{BS} mobility.

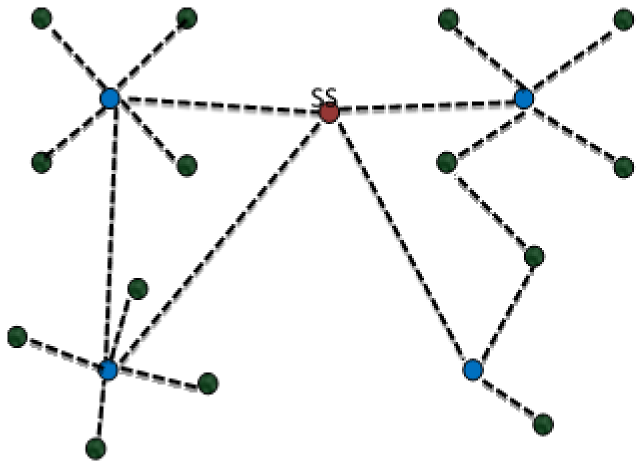

Figure 2. Summit stations

3.2 Terminologies Used For Selection Of Summit Stations

The following terminologies are used in the formation of summit stations:

- **Average center point:** The average center point is the center of the network area its coordinates are calculated by the X and Y coordinates of the sensors in the network as in [17] and are computed as C_{DX} and C_{DY}, and sn is the number of sensors.

$$C_{DX} = \frac{1}{sn}\sum_{i=1}^{sn} xi \ and \ C_{DY} = \frac{1}{sn}\sum_{i=1}^{sn} yi \quad [1]$$

- **One hop neighbor nodes(O_{HNN}) to Summit station:** One hop neighbor nodes are the nodes that are of one-hop distance from Summit Station. To cover all the nodes with less number of Summit station, every Summit station should cover as many nodes as possible

- **Mean hop distance:** Mean hop distance is assessed by the mean distance of one-hop neighbor nodes covered by the Summit Station.

$$M_{HD} = \frac{\sum_{i=1}^{O_{HNNi}} D_{ist}(C_{Di},nbj)1}{|O_{HNNi}|} \qquad [2]$$

- **Furthest points (FP):** To form a well-organised path for M_{BS}, furthest points (FP) are formed among the sensors of the network and are determined by computing the minimum and maximum values of both coordinates of X and Y minimum mn and maximum mx of sensor locations.

$$(X_{mn}, Y_{mn}), (\frac{X_{mx}}{2}, Y_{mn}),(X_{mx}, Y_{mn}), (X_{mx},\frac{Y_{mx}}{2},),(X_{mx}, Y_{mx}),(\frac{X_{mx}}{2}, Y_{mx}), (X_{mn}, Y_{mn}) \ and \ (X_{mn},\frac{Y_{mx}}{2})$$

- **Most Preferred distance(M_{PD}):** The route of the Summit Stations should not be very near or very far from the centre of the network area because it will increase the hop counts. It should be in the middle of the centre and the furthest point of the network area and is called the Most Preferred distance(M_{PD}).

$$M_{PD} = \frac{\sum_{i=1}^{CP} D_{ist}(C_{DXY}, F_{Pi})}{|2CP|} \quad [3]$$

Where CP is the no. of furthest Points.

3.3 Proposed Algorithm EEDG Design And Implementation

The proposed algorithm consists of three phases. During each round the following steps are carried out:

- Selection of Summit Stations

1. Selection of summit station by using K-means.

2. Reducing them by calculating the weight value and selecting the summit stations with maximum weight values.

- Mobile base station path Formation.

1. Generating random swarming points by considering current summit station locations.

2. Applying artificial fish swarm optimization behaviors.

3. Fitness is calculated for each behavior set. The behavior set that gives maximum Fitness is selected.

- Wireless Mobile Charging

1. In the process if any node's energy falls below the threshold then the mobile power supply is sent to that particular node by the base station to recharge it.

2. The path of mobile power suppliers is also calculated by AFSO.

3.3.1 Selection of Summit Stations.

Network loads set of locations of S_S (C_L) by using K-means calculations(Kaswan, Nitesh, and Jana 2017). Next the network reduces the number of locations S_S corresponding to reporting range R_R of the sensors within their one-hop distance along with the least hop distance. And the selected S_S are not very further or very closer to the network center. This is done by using weighted values (Kaswan, Nitesh, and Jana 2017).

The weighted value W_V is computed by considering the parameters which will influence the location of the summit station.

O_{HNN}: To cover all the nodes with a fewer number of Summit stations, every Summit station should cover as many nodes as possible. So,

$$W_V \; \alpha \; O_{HNNi} \quad [4]$$

Distance to M_{PD}: If the distance between the S_s and M_{PD} increases then hop counts will also increase. So,

$$W_V \; \alpha \; \frac{1}{mod(M_{PD} - AD_{ist}(C_{DXY}, C_{Li}))} \quad [5]$$

Mean hop distance: Energy required to send the data is directly proportional to communication distance.

$$W_V \; \alpha \; \frac{1}{|M_{HDi}|} \quad [6]$$

Combining the above equations, we get,

$$W_V = \frac{O_{HNNi'}}{mod(M_{PD} - AD_{ist}(C_{DXY}, C_{Li}))\, M_{HD}i} \quad [7]$$

These values normalize W_{Vnew} by taking the ratio between each value and its cumulative values.

$$O_{HNNi'} = \frac{|O_{HNNi'}|}{\max |O_{HNN}|} \quad [8]$$

$$M_{HDi'} = \frac{|M_{HDi}|}{\max |M_{HD}|} \quad [9]$$

$M_{PDi'} = \frac{mod(M_{PDi} - D_{ist}(C_{DXY}, C_{Li}))}{\max(mod(M_{PDi} - D_{ist}(C_{DXY}, C_{Lj})))}$ [10]

We get the weight W_{Vnew} as,

$W_{Vnew} = \frac{O_{HNNi'}}{M_{PDi'} M_{HDi'}}$ [11]

Algorithm 1: Selection of Summit Stations

Inputs: Set of Sensors, O_{HNN} , M_{HD}, M_{PD}, C_{DX}

Output: Set of C_L*selection*

- *Initiate* $C_L(S_{n1...}S_n)$ *=K-Means(*S_n*, n)*
- *for i =1 to* C_L
- *If* S_n *in* C_L *<=1 then*
- *Remove* S_n *from* C_L
- *end If, end for*
- *If* (C_L*==0) then halt, end If*
- *for i = 1 to* C_L*start*
- *Compute weight* C_L *, end for.* calculate weight using equation (11)
- *Find* S_S *with maximum* W_V *for∀* C_L*.*
- *Eliminate nominated* C_L *from next computation*
- *Remove the* S_n *which is covered by eliminated* C_L
- *Call* A_{FSD}*To find the traveling path for* M_{BS}

During S_S selection in each iteration, Summit Station covered with the least sensors are eliminated. And the sensor covered by the eliminated S_S is removed. The weight of residual S_S locations is calculated to decide the finest weighted value. In each cluster, the maximum weighted value is measured and marked as the current S_S.

Once t*he* S_S is computed, B_S transmits the *list of* S_S to every node in the network. The sensors get updated and share the data to the specified S_S . During the data-hearing process, the maximum weights S_S are utilized for data transportation, and the remaining nodes are turned to hibernate mode by the base station. At the beginning of each round S_S are updated. The route of M_{BS} is formed by using artificial fish swarm optimization.

3.3.2 Mobile Base Station Path Formation

In cluster communication, nodes sense the environmental changes and transmit the observations to the cluster center location C_L i.e. S_S . The base station computes M_{BS} routes as per artificial fish swarm optimization. The M_{BS} is moved to S_S terminal according to the route provided by the B_S to collect the data .

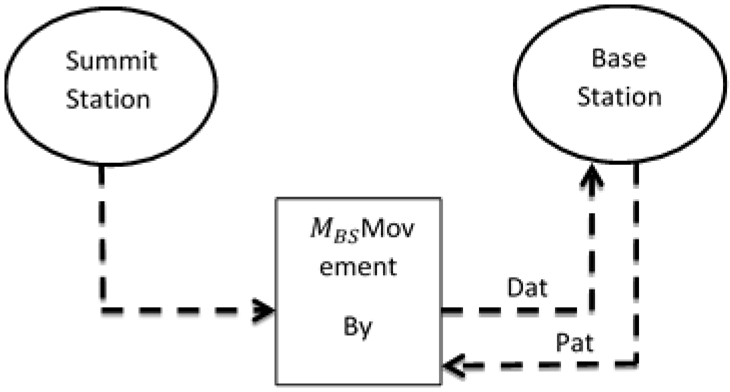

Figure 3. MBS Movement

During artificial fish swarm optimization, random swarming points are generated based on current S_S terminal points. Based on swarming points, Fitness is examined in terms of preying value by looking at the number of nodes reached by S_S terminal, the traveling duration to the swarming point ($i.e. S_S$ terminal), and the distance from sensors and data distance from sensor location to M_{BS} . At each iteration, the best Fitness solution is determined.

3.3.2.1 Artificial fish swarm algorithm

Generally, fish migrates to network fields to find better feed by their knowledge or using swarm hunt. The process is designed by considering swarm as number of Generations (G), prey (K), and unconfined-flowing, besides accompanying performances. The food consistency level in distinct localities is the key objective and to search maximum feed position. (Azizi et al. 2015)

- The state of A_{FSOi} , vector K = (k1, … k*n*), and k*i*(*i* = 1…*n*) are optimization variables, where n is number of variables. R produces random solutions from 0 to 1.
- The present feed stability level as the objective function, ObjFunction Z = *f*(K*i*). Node view is the vision of A_{FSOi} and *Phase* achieves peak magnitude of each move. (Mohd Rosely, Salleh, and Zain 2019; Neshat et al. 2012)
- Identify SUMMIT stations in the network.
- Applying artificial fish swarm optimization behaviors. Every behavior produces a set of S_S terminal.
- Select the finest $S_S$terminal set for M_{BS} data collection.
- $C_L$represent number of clusters centers i.e S_s, $D_{ist}$is the visual distance, and *Δ*is the coverage factor where (0 <*Δ*<1).
- The D_{ist} between two A_{FSOi} ,*Ki* and K*j* positions is accessible by D_{ist} estimation of (X, Y) by Euclidian distance (Azizi et al. 2015)and computes transmission delay *TxDelay*.

Distance = $D_{ist} = \sqrt{|X1 - X2|^2 + |Y1 - Y2|^2}$
[12]

TxDelay = $\sum_{i=1}^{R_R} Delay$ Check $\forall S_S$ terminal [13]

- The finest A_{FSOi} location is computed and most covered *ncovered* sensor *mass location factor* δ(0 < δ < 1) is exemplified(Mohd Rosely, Salleh, and Zain 2019; Neshat et al. 2012). A_{FSOi} covers S_s and nodes within its viewing space. At a particular stopping point if the M_{BS} can collect data from more than one S_s or nodes then it increases its coverage with less distance.

If(D_{ist}< coverage)

then ncovered++.

- Compute FITNESS for every behavior's S_S terminal set .
- Fitness function is represented as below. Maximum Fitness represents best location set.

Input =(α TxDelay + β D_{ist}) [14]

Fitness ±AFSO (input) [15]

Fitness [i] = $K = \frac{fitness}{ncovered}$ [16]

M_{BS} Movement Decision (C_L, Fitness, SwarmingCount)

$$Final\ Fitness = max \frac{\sum_{i=\in R_R} D_{ist(S_n,S_S)}}{ncovered} \quad [17]$$

- Select the behavior set that gives maximum Fitness.
- BS instructs M_{BS} to move to specific S_s terminal set

Algorithm 2: *Mobile Base Station Path* Inputs: Swarm SW, Prey K, $K = \frac{1}{K+1}$

- SW =Swarming (K)

- Select Random Number (0, K-1) + 1
- Initial SwarmingCount = 0
- Update SwarmingCount ++
- Increment Iterations++
- Initial prey S = Preying Point (Prey)
- Obj = ObjFunction(S) – ObjFunction (prey)
- if(Obj < 0)
- Prey = S, else
- Select R = Next Random Solution (0,1)
- If R $< \frac{\text{OBJ}}{\text{SW}}$
- Prey = S;
- Update Last Value = Prey
- If(ObjFunction(K) != ObjFunction(prey) || swarm < SwarmingCount)
- return Prey

The same is repeated until all S_S terminals in the network are covered. Once the optimal route is formed, M_{BS} are moves and transmits the polling point message to the nodes to assemble data from summit stations. Once the mobile base station completes visiting all S_S terminals, it moves to reporting location and handover data to the base station as shown in figure 3 and it continues data collection with the next updated path.

3.3.3 Mobile Charging

In the process of sensing, transmission, etc., the sensor may run out of energy. If any node's energy falls below the threshold value (here when nodes energy falls below 30%), it notifies the base station with a critical energy message. Then mobile power supplier M_{PS} is driven to the location of the sensor to recharge its battery(figure 4) as per B_S direction, M_{PS} stands at the S_S terminal of the demanded node region for a certain time to share power through wireless sockets. At the same time, if any other nodes in the region prefer to renew energy, they can recharge through the wireless sockets. The B_S develops path of M_{PS} by artificial fish swarm optimization algorithm by considering the requested node location as a reference point. Sensor power charging consists of the following:

- Total movement period T_M of the M_{PS}
- Total power-consuming T_C time of all the sensors
- The relaxation time T_R of the M_{PS} at B_S.

n^t signifies the n^{th} period , and hence the subsequent calculation(Tu et al. 2017):

$n^t = (T_C + T_R + T_M)$ [18]

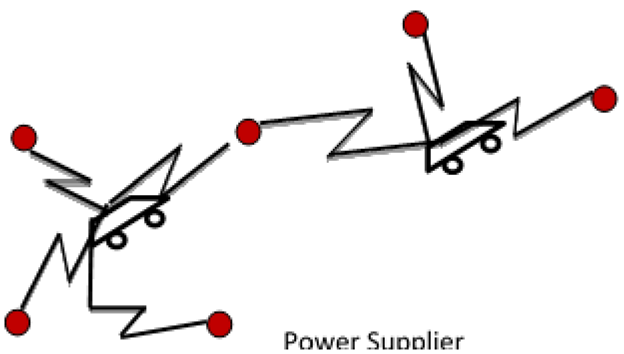

Figure 4. Charging the sensors through mobile chargers

Results and Discussion

The EEDG protocol is verified with existing protocols like GAECH and K-means calculations and simulation is carried out by multiple simulated tested scenarios. Based on each node's packet sensing period, the approximate sensing time gap is acknowledged as packet interval, this is selected between 0.5 to 0.1 seconds randomly, and the total simulation time is addressed from 200 seconds to 250 seconds with 100 to 150 sensors situated in the network region. The Network Simulator version-2 - NS2 tool is used to design and implement the protocol. The EEDG protocol setup parameters are in the reflecting table 1.

Packet delivery ratio (PDR) is the rate at which packets are delivered at the Base station. Can be calculated as

$$\text{PDR} = \frac{\text{recievedpacket} * 100}{\sum_1^n sentpacket} \qquad [19]$$

recievedpacket are the number of packets received by the Base station and *sentpacket* are the number of packets sent by the source nodes and n is number of nodes. Figure 5 shows packet delivery ratio of EEDG and other protocols. EEDG has 20% and 23% more packet delivery ratio than GAECH and K-Means.

Parameters	Value
Sensors	100
Mobile Base Stations	5
Power Suppliers	3
MAC Protocol	Mac/802.11
Packet Size	512 Bytes
Initial energy	1J
E_{tx}	0.02J
E_{rx}	0.01J

Table 1. Simulation parameters

Because EEDG develops the route based on cluster formation and highest weighted SUMMIT stations. Mobile base station collects the data packets from individual cluster points simultaneously by the base station defined intersection point at specified period. Likewise, mobile power supplier restocks the node battery if it falls below threshold.

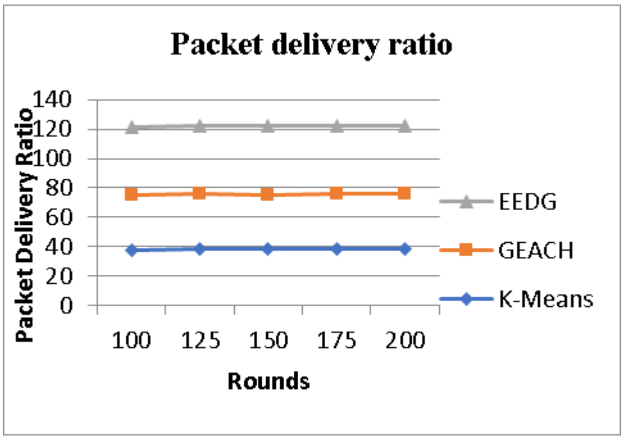

Figure 5. Packet delivery ratio V/S Rounds

Figure 6 shows the Throughput Vs Number of rounds graph. EEDG maximizes the throughput by 20% more than K-means and 91% more than GEACH. Figure 7 shows the Jitter Vs Rounds graph. Jitter is less in EEDG when compared with other protocols. Delay: The time between the packet sent and the packets received is called delay time and can be calculated as

Delay = PRectime - PSentime [20]

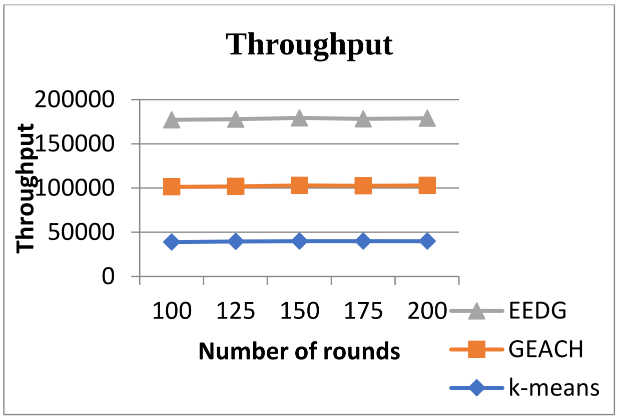

Figure 6. Throughput V/S Rounds

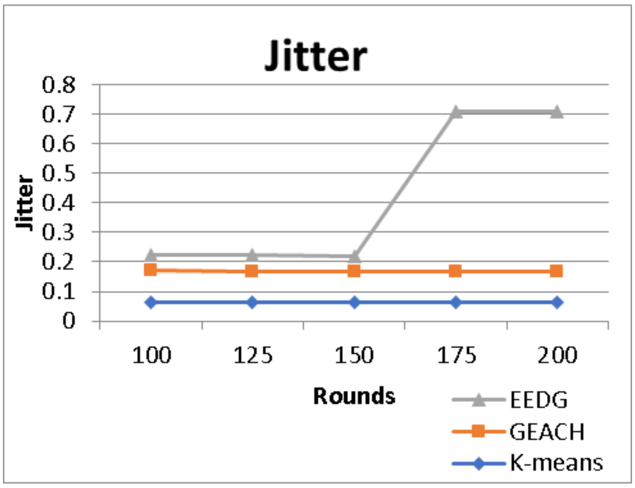

Figure 7. Jitter V/S Rounds

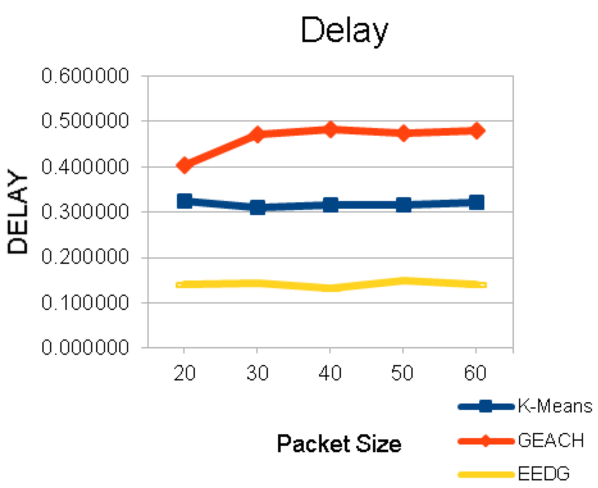

Figure 8. Delay V/S packet size

The average delay for all the packets can be calculated as,

$$\text{Avg Delay} = \frac{\sum_{0}^{n} \text{PRectime} - \text{PSentime}}{time} \quad [21]$$

PRectime is the time at which the packet is received by the BS and PSentime is the time the packet is sent.

The Delay graph in figure 8 explains EEDG path stability because of enhanced computations and route election. The graph shows minimal delay of EEDG than GAECH and K-Means.

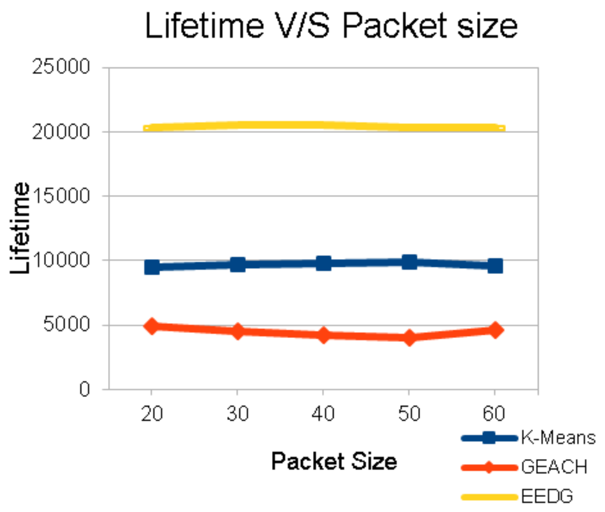

Figure 9. Lifetime V/S packet Size

Lifetime in the graph (figure 9) defines energy management among the network nodes. Here EEDG has prolonged lifetime than other protocols. EEDG prolongs the lifetime by 52% more than K-means and 78% more than GEACH. EEDG used a mobile charger to recharge the nodes. When a mobile charger receives energy-critical notification from a node it moves to that specific node and recharges it, and other nodes in the vicinity of the mobile charger can also recharge. This helps in increasing the network lifetime. Good put represents the volume of received data bit counts per second at the destination. Figure 10 represents the result of Good put with three protocol comparisons. Among all the three protocols EEDG results with strongest Good put. The percentage improvement in goodput is 55% more than K-means and 93% more than GEACH. EEDG focused on building a systematic network structure during

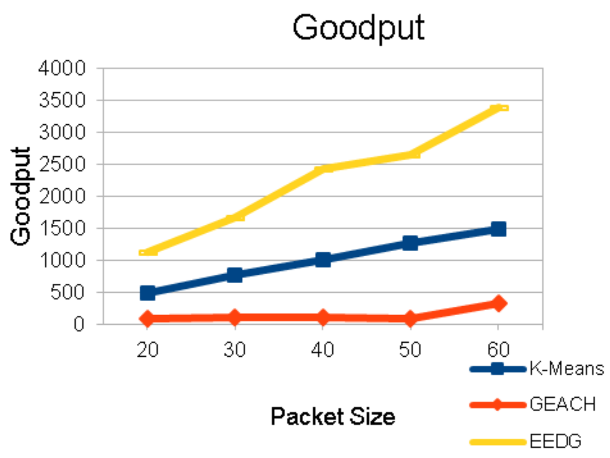

Figure 10. Goodput V/S Packet size

data communication collected data using the mobile base station and preserved node energy with the support of mobile power suppliers. So EEDG design obtained the greatest Good put.

5. Conclusion

In the proposed work, the selection of clusters and summit stations is based on the k-means algorithm considering the most needed distance, typical hop distance, the center location of the cluster, and the number of nodes marked by the cluster. The Summit Stations provide better coverage. The data is collected by mobile base stations by visiting Summit stations. The path of mobile base stations is formed by artificial fish swarm optimization. The mobile sink balances the network. If any node has low energy, then the mobile power supplier moves to the location of that sensor to recharge it. The path of the mobile power supplier is also formed by artificial fish swarm optimization by considering the transmission delay of the node.

The proposed method is compared with existing algorithms in terms of packet delivery ratio, delay, lifetime, and goodput. Simulation results prove that EEDG performs well. In the future we can form distributed network and build the path with interference reduction and congestion avoidance in an optimized way

References

1. K. Rajkumar, B. Monica, and K. R. Sekar, "The study on nature-inspired principles for solving routing issues in wireless sensor network," Int. J. Innov. Technol. Explor. Eng., vol. 8, no. 6, pp. 762–766, 2019.
2. H. Hassan, W. M. Shah, A. M. Husien, M. S. Talib, A. A. J. Mohammed, and M. F. Iskandar, "Clustering approach in wireless sensor networks based on K-means: Limitations and recommendations," Int. J. Recent Technol. Eng., vol. 7, no. 6, pp. 119–126, 2019.
3. S. Dash, S. S. Mallick, R. C. Hansdah, and A. R. Swain, "A distributed approach to construct hierarchical structure for routing with balanced energy consumption in WSNs," Proc. - Int. Conf. Adv. Inf. Netw. Appl. AINA, vol. 2015-April, pp. 382–388, 2015, doi: 10.1109/AINA.2015.210.
4. N. Purushothaman and V. Saminadan, "Energy-balance routing and throughput maximization for wireless sensor networks," Proc. Int. Conf. Circuits, Commun. Control Comput. I4C 2014, no. I4c, pp. 208–211, 2014, doi: 10.1109/CIMCA.2014.7057792.
5. P. Krömer and P. Musilek, "Bio-inspired Routing Strategies for Wireless Sensor Networks," pp. 155–181, doi: 10.1007/978-3-319-15916-4.
6. P. C. S. Rao, P. K. Jana, and H. Banka, "A particle swarm optimization based energy efficient cluster head selection algorithm for wireless sensor networks," Wirel. Networks, vol. 23, no. 7, pp. 2005–2020, 2017, doi: 10.1007/s11276-016-1270-7.
7. B. Baranidharan and B. Santhi, "GAECH: Genetic algorithm based energy efficient clustering hierarchy in wireless sensor networks," J. Sensors, vol. 2015, 2015, doi: 10.1155/2015/715740.
8. M. Neshat, G. Sepidnam, M. Sargolzaei, and A. Najaran, "Artificial fish swarm algorithm : a survey of the state- and indicative applications," 2012, doi: 10.1007/s10462-012-9342-2.
9. O. Helmy, S. Ahmed, and A. E. Hassenian, "Artificial Fish Swarm Algorithm for Energy-Efficient Routing Technique," pp. 509–519, 2015, doi: 10.1007/978-3-319-11313-5.
10. Tunca, S. Isik, M. Y. Donmez, and C. Ersoy, "Distributed mobile sink routing for wireless sensor networks: A survey," IEEE Commun. Surv. Tutorials, vol. 16, no. 2, pp. 877–897, 2014, doi: 10.1109/SURV.2013.100113.00293.
11. E. M. Saad, M. H. Awadalla, and R. R. Darwish, "Adaptive Energy-Aware Gathering Strategy for Wireless Sensor Networks," Int. J. Distrib. Sens. Networks, vol. 5, no. 6, pp. 834–839, 2009, doi: 10.1080/15501320903235400.
12. O. León, J. Hernández-Serrano, and M. Soriano, "Securing cognitive radio networks," Int. J. Commun. Syst., vol. 23, no. 5, pp. 633–652, 2010, doi: 10.1002/dac.
13. M. Xiao, X. Zhang, and Y. Dong, "An Effective Routing Protocol for Energy Harvesting Wireless Sensor Networks," 2013 IEEE Wirel. Commun. Netw. Conf., pp. 2080–2084, 2013, doi: 10.1109/WCNC.2013.6554883.
14. P. Zhang, G. Xiao, and H. P. Tan, "A preliminary study on lifetime maximization in clustered wireless sensor networks with energy harvesting nodes," ICICS 2011 - 8th Int. Conf. Information, Commun. Signal Process., 2011, doi: 10.1109/ICICS.2011.6174242.
15. S. Guo, C. Wang, and Y. Yang, "Joint mobile data gathering and energy provisioning in wireless rechargeable sensor networks," IEEE Trans. Mob. Comput., vol. 13, no. 12, pp. 2836–2852, 2014, doi: 10.1109/TMC.2014.2307332.
16. Kaswan, K. Nitesh, and P. K. Jana, "International Journal of Electronics and Communications (AEÜ) Energy efficient path selection for mobile sink and data gathering in wireless sensor networks," AEUE - Int. J. Electron. Commun., vol. 73, pp. 110–118, 2017, doi: 10.1016/j.aeue.2016.12.005.
17. R. Azizi, H. Sedghi, H. Shoja, and A. Sepas-moghaddam, "A N OVEL E NERGY A WARE N ODE C LUSTERING A LGORITHM F OR W IRELESS S ENSOR N ETWORKS U SING," vol. 7, no. 3, pp. 103–115, 2015.

18. N. F. L. Mohd Rosely, R. Salleh, and A. M. Zain, "Overview Feature Selection using Fish Swarm Algorithm," J. Phys. Conf. Ser., vol. 1192, no. 1, 2019, doi: 10.1088/1742-6596/1192/1/012068.
19. W. Tu, X. Xu, T. Ye, and Z. Cheng, "A Study on Wireless Charging for Prolonging the," pp. 1–14, 2017, doi: 10.3390/s17071560