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A MODIFIED CLUSTERING AND ROUTING METHOD FOR ENHANCING NETWORK LIFETIMEOF WSN

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***Abstract*—The proposed procedure utilizes Joint Clustering Approach in which two distinctive cluster strategies are blended which improved the network lifetime of the network. The future headway of the work can be greater progression should be possible in the proposed technique with the goal that network lifetime by utilizing diverse more methodologies. This paper proposed joint clustering convention approach. It considers all out-recreation region 500X500 meter and nodes region taken 200, 800 during nodes reproduction. Proposed technique based on joint cluster while past methodology based on novel strategy. Network move rate or throughput is accomplished by proposed strategy is 275Kbps while past it is accomplished 250Kbps. Reenactment time is additionally diminished up to 835 Sec. The general energy utilization is 380J while past it is 1000J. In this manner it very well may be say that the proposed technique approach gives noteworthy better execution in wireless sensor network than past methodology.**

***Keywords*—Joint Clustering Approach, WSN, Cluster head, Clustering, Routing, Life time and Throughput *etc*.**

INTRODUCTION

The Advancement in small scale hardware framework is the significant reason for the advancement of WSN in the period of twenty first century. WSN has gotten fundamental for day-by-day client, without WSN our work would have been very weight or hard. WSN are skilled of detecting, changing and course of the data. These sensor nodes are commonly organized in a various space like in war space where human are difficult to reach. WSN create enormous measure of data in type of bits or stream. These nodes contact over an exact scope of nodes which are outline in a specially appointed structure and get the data to the sink. WSN have many constrained assets like restricted energy, memory, calculation power, correspondence limit and so on. There are a few IoT applications which are based on WSNs [1], for example, social insurance observing, vehicular checking, fire timberland observing, road checking, and condition checking and so on. These networks are the type of framework that is made of hundreds or thousands of wireless sensors with a lot of assets which are utilized in an extremely wide scope of field. In the earlier years, we have seen the utilization of recently created conventions for data assortment in WSN.These sensors are disseminated in a region which is being watched and data is gathered continuously and identified with the physical condition [2]. Sensors take a shot at batteries. It is impracticable to change the battery for the network. For expanding the network lifetime, it is awesome advance for structuring the calculation so the transmission amount can be diminished. Various undertakings are taken to reduce the quantity of unfortunate transmissions in sensor network. The data collection strategies increment energy utilization in WSN.

"The data amassing is a framework to join data from various sensor nodes to abstain from dreary data and give a rich and multi-dimensional point of view on the watching condition. The data gathering figuring can decrease the amount of transmission by allowing the aggregator node to transmit only the essential data, not the overabundance data".

A. ORIGIN OF WIRELESS SENSOR NETWORK

WSN is a relationship of minimal miniaturized scale sensors with wireless correspondence abilities. In the

same way as other development advancements, WSN owe its root in overwhelming mechanical applications just as military applications. The principal wireless network that is inline with the most recent WSN is the Sound Reconnaissance Framework (SOSUS) created on lowered acoustic sensors. Sensors in SOSUS were conveyed in the Pacific sea Atlantic seas. Invigorated by the improvements relating to Web in 1960s and 1970s to build up the equipment for the present Web, Resistance Propelled Exploration Activities Office (DARPA) started the Network (DSN) program in 1980[21]. The rationale was to investigate the structure provokes identified with WSN. With the introduction of DSN and its infiltration into instruction through Carnegie Mellon College and the Massachusetts Organization of Innovation, WSN innovation could locate its base in family, training and non military personnel logical exploration.

Very soon, open and private networks began conveying sensors to screen air quality, recognize woods fire, conjecture climate, forestall catastrophic event and so forth. The sensors anyway around then were cumbersome, costly and utilized exclusive conventions. The utilization of such WSNs therefore overloaded the business which utilized it. This unbalanced connection of significant expense with low volume of sensors declined their unavoidable use.

Understanding the capability of the network, industry and the scholarly community held hands to comprehend the designing difficulties related with sensors and lead to the creation of present day sensors: low cost small scale size sensors, having disentangled turn of events and support assignments

B. Challenges in Designing of Wireless Sensor Network

A significant issue in structuring of wireless sensor network is of energy impediment. As sensor networks are normally positioned in regions which are more enthusiastically to reach, it is hard to supplant them or energize their batteries. The network lifetime is legitimately reliant on energy effectiveness. Thusly, plan of solid and efficient sensor nodes and routing convention is a significant structure challenge. A sensor node expends energy for detecting simple data, handling the data and transmitting the data. Another issue is structuring of use explicit wireless sensor network arrangement for various assignments may need to detect distinctive kind of data [7].

II. OBJECTIVE

The network performance of wireless sensor network is very challenging. The main objective of this research work is to design joint cluster algorithm which is a combination of two different clustering algorithms. The first algorithm of the combination is Energy Efficient Hierarchical Clustering and the second algorithm in the combination is Modified Low Energy Adaptive Clustering Hierarchy. These both algorithms are combined to form a Joint Cluster approach.So the network life time, dead node, throughput etc. parameter improvement is key goal of this research.

III. PROPOSED METHOD

In The main contribution of this research work is as follows-

- To design joint clustering and routing (JCR) protocol for reliable and efficient data collection in large-scale wireless sensor network.
- To make JCR using energy efficient hierarchical clustering and modified low energy adaptive clustering hierarchy protocol approach.
- Theoretical analysis and simulation results will prove the connectivity and efficiency of the network topology generated by JCR.
- To calculate performance parameters also like throughput, network node lifetime, dead node, total energy, packet size, simulation time etc.

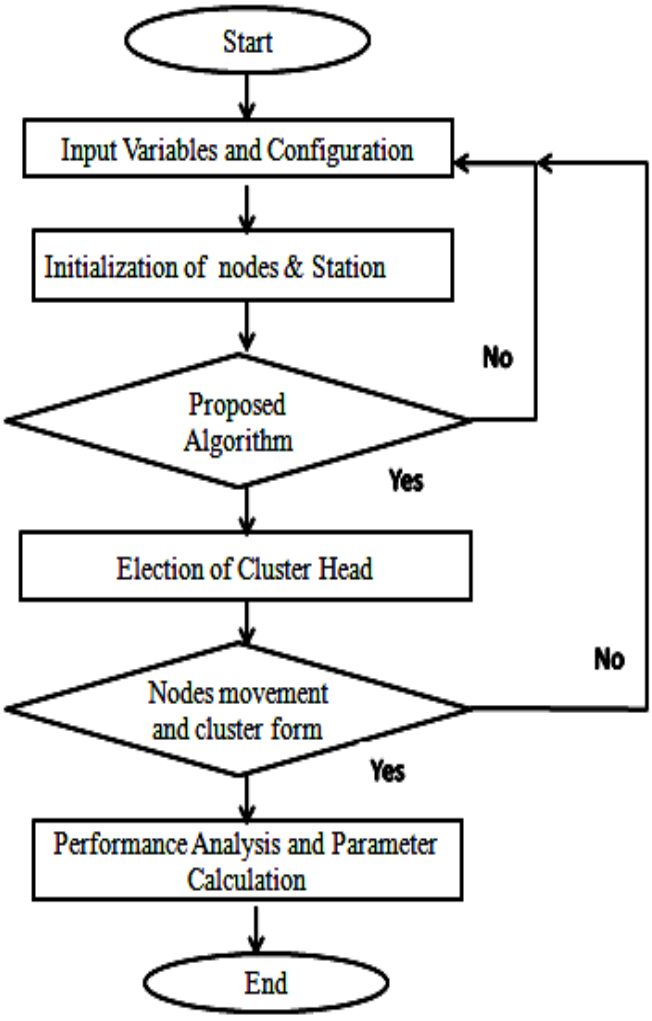

Figure 1 Flow Chart

Algorithm:

Step 1: Assign the number of node, the probability value.

Step 2: For the hop count h initialize the value of S(n+1)

Step 3: Check whether there are cluster head at the initial stage .

Step 4: Count the number of Cluster Head by CountCHs=0

Step 5: Initialize the Value of CH=1 then verify the number of live node and dead node.

Step 6: Check the count of number of Packets to CH and Packets to BS and Packets to BS per Round.

Step 7: Calculate the number of epoch performed.

Step 8: Check the number of dead node.

Step 9: Perform the election of Cluster Head to the normal nodes.

Step 10: Calculate the energy dissipated.

Step 11: Calculate the number of Cluster Head.

A. METHODOLOGY

Proposed methodology is joint clustering and routing (JCR), which implemented using energy efficient hierarchical clustering and modified low energy adaptive clustering hierarchy protocol approach

B. Energy Efficient Hierarchical Clustering-

Energy Efficient Hierarchical Clustering (EEHC) is a randomized, distributed clustering algorithm that prolongs the network lifetime. In this part sensor nodes are organized into clusters with a hierarchy of cluster heads. the CHs collects the information from the nodes within their clusters and send the aggregated data to the BS through the hierarchy. This algorithm is based on two stage clustering: single-level and multi-level clustering. At the single-level clustering stage, each sensor node becomes a CH on the basis of a pre-defined probability p and announces itself as the volunteer CH to its neighbors within khops distance. Any node which receives this announcement becomes member of the closest cluster. If a node does not hear any announcement within a preset time interval t, then it will become a forced CH. This time interval t is calculated on the basis of the duration for a packet to reach a node that is k-hops away. The energy consumed for sending the information to the sink depends on the parameters p and k.

At the second stage, same process is applied from bottom-up to multilevel clustering. Assume there are h levels in a clustering hierarchy, among which level-1 being the lowest one and level-h being the highest one. Then level-1aggregates the data from its cluster members and send it to level-2 CHs, and so on. Finally the level-h CHs send the aggregated data to the base station. The cost of transmitting the information to the base station is the power consumed by sensor nodes to send data to level-1, then energy used by level-1 CHs to the base station via h – hop CHs at different hierarchical levels.

C. Modified low energy adaptive clustering hierarchy

That leads us to start thinking about constructing the networks. To further improve energy efficiently, two approaches introduced in the papers are summarized in the following:

LEACH is a cluster-based wireless sensor networking protocol. LEACH adapts the clustering concept to distribute the energy among the sensor nodes in the network. LEACH improves the energy-efficiency of wireless sensor networking beyond the normal clustering architecture. As a result, we can extend the life time of our network, and this is the very important issue that is considered in the wireless sensor networking field.

In LEACH protocol, wireless sensor networking nodes divide themselves to be many local clusters. In each local cluster, there is one node that acts as the base station (or we can call it “cluster-head”). Hence, every node in that local cluster will send the data to the cluster-head in each local cluster. The important technique that makes LEACH be different from the normal cluster architecture (the drain the nodes battery very quickly) is that LEACH uses the randomize technique to select the cluster-head depending on the energy left of the node.

After cluster-head is selected with some probability, the cluster-heads in each local cluster will broadcast their status to the sensor nodes in their local range by using CSMA MAC protocol. Each sensor node will choose a cluster-head that is closest to itself to join that cluster because each sensor node will try to spend the minimum communication energy with it cluster head.

After the clustering phase is set up, each cluster-head will make a schedule for the nodes in its cluster. In paper LEACH, TDMA is used. For more efficiency, each sensor node could turn-off waiting for their allocated transmission.

Cluster-heads will collect the data from the nodes in its cluster, and compresses that data before transmits the data to the base station. By following this protocol, the base station will get the data from all sensor nodes that we are interested, and ready for the end-user to access the data.

D. Energy Analysis of Routing Protocols

Two conventional routing protocols in wireless network that we will discuss in this section are direct communication and minimum-transmission-energy routing protocol (MTE). In direct communication, each node connects and transmits data directly to the base station. If base station locates far away from sensor nodes, sensor node will deplete its battery quickly and shortens the system lifetime. In minimum-transmission-energy, node routes data to the base station via its neighbors. Each node will act as a router that route a received packet from one neighbor to another. This technique reduces the transmit amplifier energy because distance between node is shorter than the distance between node and the base station. This concept can be expressed mathematically as following::

$$ETx(K, d) = Eelec \times k + \varepsilon amp \times k \times d2 \quad (4.1)$$

$$ERx(K) = ERx\text{-}elec(k) = Eelec \times k \quad (4.2)$$

Where Eelec is the energy spent in transmitting and receiving data for a sensor;εamp is the energy spent in amplifying. Therefore, the energy is consumed for a sensor to transmit k-bits data over d meters is defined in (4.1), and

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that for receiving data is defined in (4.2). Node A will route a packet to C via B if the following equation holds:

ETx-amp(k, d = dAB) + ETx-amp(k, d=dBC) <ETx-amp(k, d=dAC)----------(4.3)

However, we need to take into an account that, in minimum-transmission-energy, each message needs to go through multi-hops and the total energy might ends up grater than direct transmission.

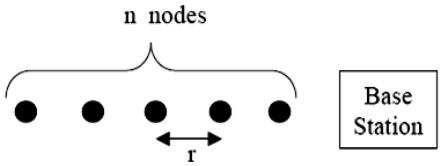

Figure 2: Simple linear network

Assume we have a linear network as shown in Figure 2. The network consists of n node, each node has r distance. Therefore, the energy used in direct transmission is:

$$E_{direct} = ETx(k, d = n*r)$$
$$= Eelec * k + \varepsilon amp * k * (nr)2$$

In MTE routing, we have:

$$E_{MTE} = n * ETx(k, d = r) + (n-1)*ERx(k)$$
$$= n(Eelec*k + \varepsilon amp *k*(nr)2$$

Therefore, direct transmission uses less energy than MTE routing if:

$$E_{direct} < E_{MTE}$$
$$k(Eelec + \varepsilon ampn2r2) < k((2n - 1)Eelec + \varepsilon amp nr2$$

According to simulation result from [4.1], it can be concluded that when a distance between nodes is short and the radio electronic is high, data transmission perform better in term of energy efficiency than MTE routing. Therefore, when we consider designingthe most energy-efficient protocol, we need to take into account the network topology.

IV. SIMULATION AND RESULT

The present algorithm is implemented using MATLAB software. The following parameters considering for the simulation-

Table 1: Simulation parameters – Input

Sr.No.	Parameters	Values
1	Software	MATLAB 8.3
2	Tool	Communication tool box
3	Simulation area	750m X 750m
4	Total rounds	1200
5	Total nodes	100 to 1200
6	Methodology	Joint Cluster

Table 1 is showing the input simulation parameter values. The total simulation area considers 750m X 750m. Total rounds during simulation are 1200 round. Total nodes are 100 to 1200 number and implementation using joint Cluster methodology.

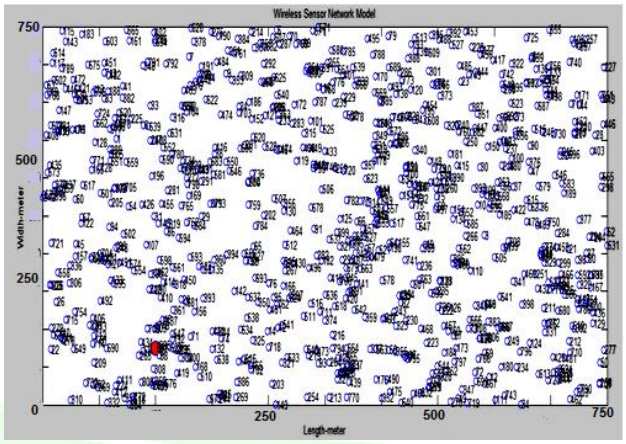

Figure 5.3: Simulation area 750m X 750m

Figure 5.3 show the simulation scenario where length and width of wireless sensors network area is 750m X 750m. Total nodes taken are 100 to 1200. In this step all variables, mobile agent and configuration are initialize the simulation.

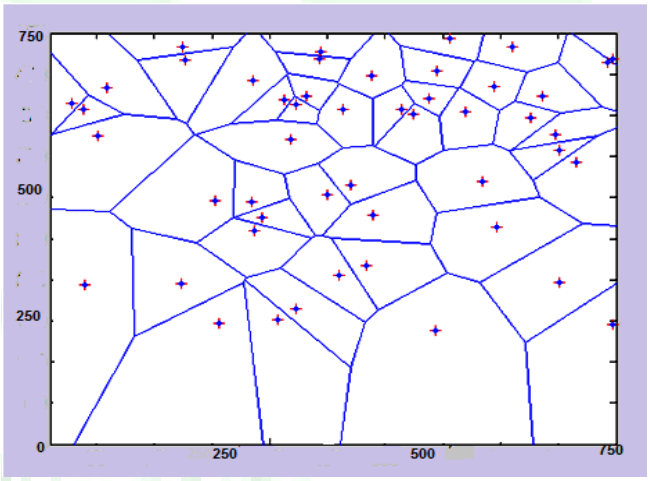

Figure 5.4: Clusters form initialization

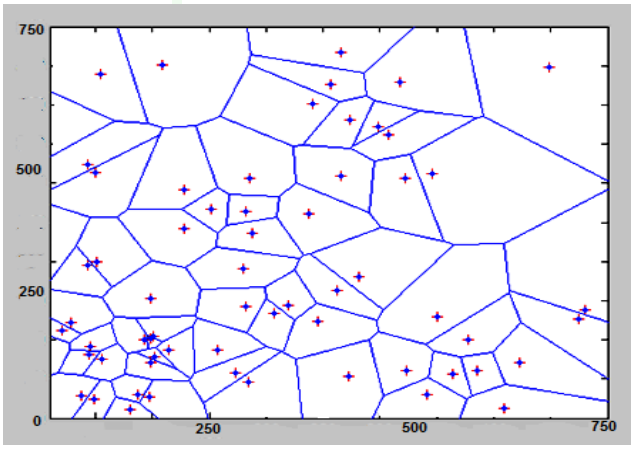

Figure 5.5: Clusters form

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This figure 5.5 presents cluster formation. Here applied proposed algorithm i.e joint cluster approach. The combination of Energy Efficient Hierarchical Clustering and Modified low energy adaptive clustering hierarchy are using for joint clustering.

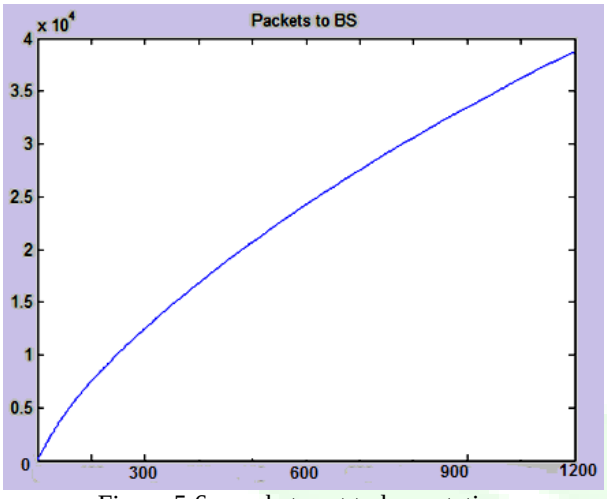

Figure 5.6: packet sent to base station

This figure 5.6 presents the output performance of nodes during simulation. The total packets sent to base station is approx $4X10^4$ bits/sec or it is 40Kbps.

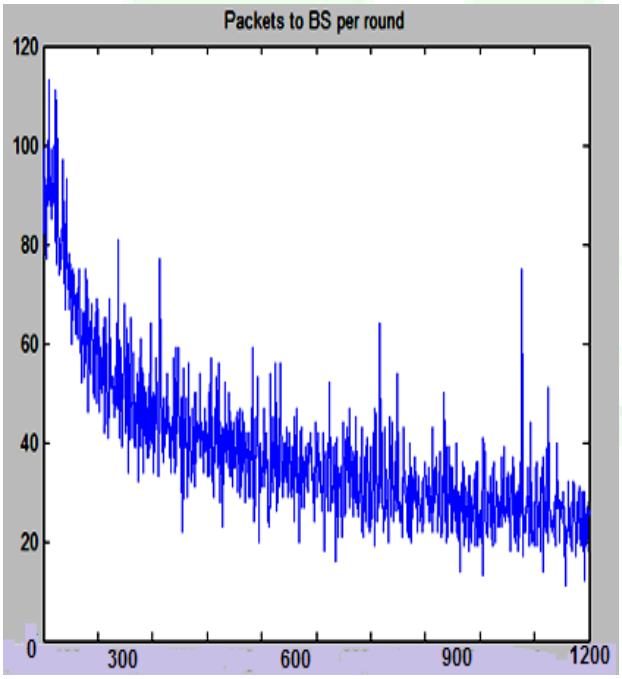

Figure 5.7: packet sent to base station per round

This figure 5.7 presents the transmission of data packets during per round to the base station. It can be say that data packets are transmit in each round.

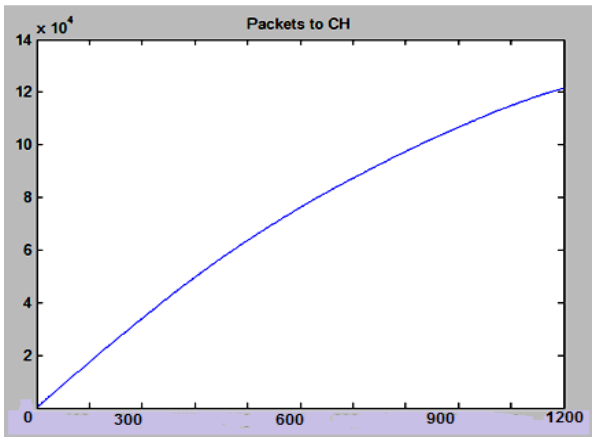

Figure 5.8: packet to cluster head

This figure 5.8 presents the transmission of data packets during per round to the base station. It can be say that data packets are transmit in each round.

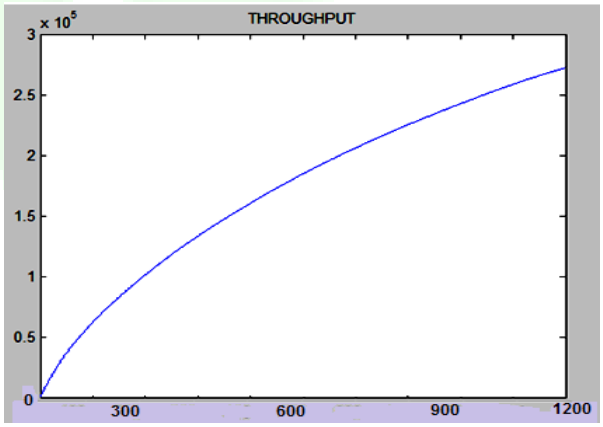

Figure 5.9: Data transmission rate or throughput

This figure 5.9 presents the data transmission rate or throughput rate. It is clear that the throughput is 275Kbps.

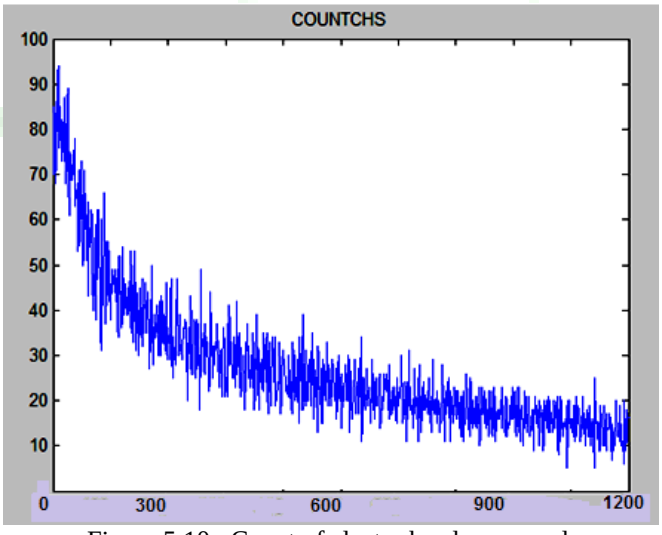

Figure 5.10: Count of cluster heads vs rounds

This figure 5.10 shows that the total count of cluster heads during simulation. Total 1000 rounds simulation

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performed and cluster head form in each round. No vacant CH during simulation.

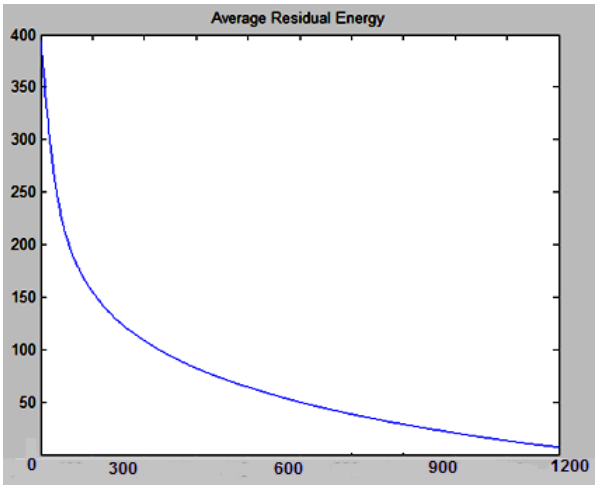

Figure 5.11: Average residual energy

This figure 5.11 shows that the average residual energy of nodes. Therefore total 380 J energy takes by nodes.

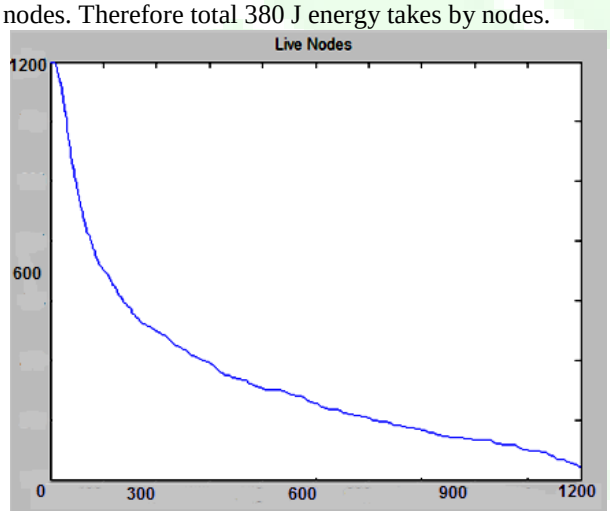

Figure 5.12: live nodes

This figure 5.12 shows that the total lives nodes during round of simulation. Therefore total 200 nodes live in 1000 rounds.

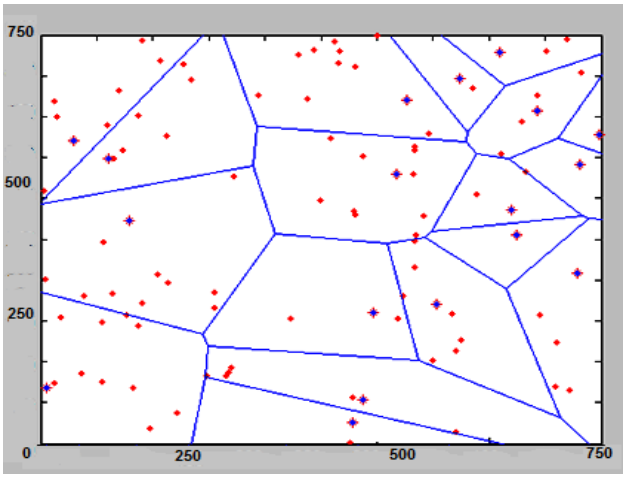

Figure 5.13: live nodes and dead nodes simulation

This figure 5.13 shows that the total live nodes and dead nodes simulation. During simulation nodes loss energy and it become dead during execution time.

Table II: Simulation parameters- output

Sr No.	Parameters	Values
1	Total live nodes	800
2	Dead node till end of simulation	100
3	Average energy consume each node	1 nJ
4	Average residual energy	380 J
5	Count of cluster heads	95
6	Throughput (Data rate)	275 Kbps
7	Packet to cluster head	140 Kbps
8	Packet sent to base station per round	110
9	packet to base station	4000

Table III: Comparison of proposed work result with previous work

Parameters	**Previous Work**	**Proposed Work**
Simulation area	500m X500m	500m X500m
Total nodes	200 to 800	200 to 800
Methodology	Novel Approach	Joint Cluster
Network transfer rate (Throughput)	250 Kbps	275 Kbps
Data size	200 byte	400 byte
Node Energy consumed	5 nJ	1 nJ
MA code size	1024 bytes	200 bytes
Execution time	1000 Sec	164.9 seconds
Overall energy consumption	1000 J	380 J

Table III shows that comparison of proposed work with previous work method. Consider total simulation area 750X750 meter and nodes area taken between 100 to 1200 during nodes simulation. Present method based on joint cluster while previous approach based on novel method. Network transfer rate or throughput is achieved by proposed method is 275Kbps while previous it is achieved 250Kbps. Simulation time is also reduced upto 835 Sec. The overall energy consumption is 380J while previous it is 1000J. Therefore it is clear that proposed methodology gives significant better results than previous approach.

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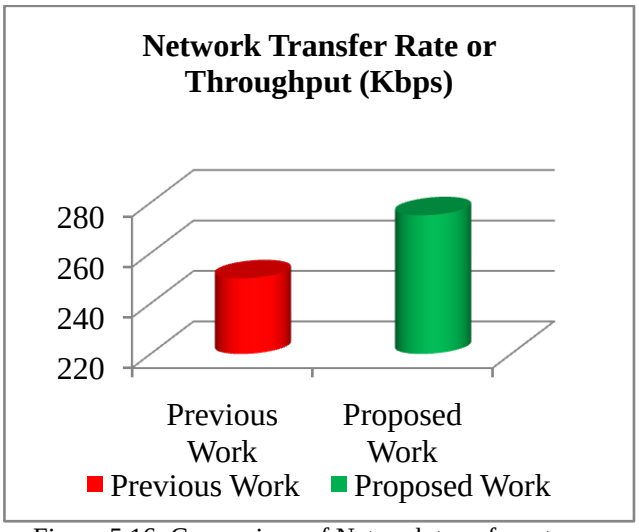

Figure 5.16: Comparison of Network transfer rate

This comparison graph 5.16 shows that network transfer rate or throughput by previous and proposed methods. Therefore 25Kbps data rate increase by proposed method.

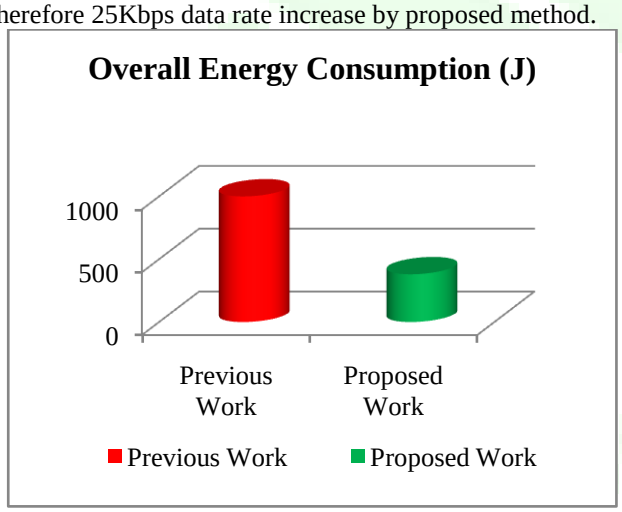

Figure 5.17: Comparison of overall energy consumption

This comparison graph 5.17 shows that overall energy consumption by previous and proposed methods. Therefore, energy consumption is reduced by 620 J.

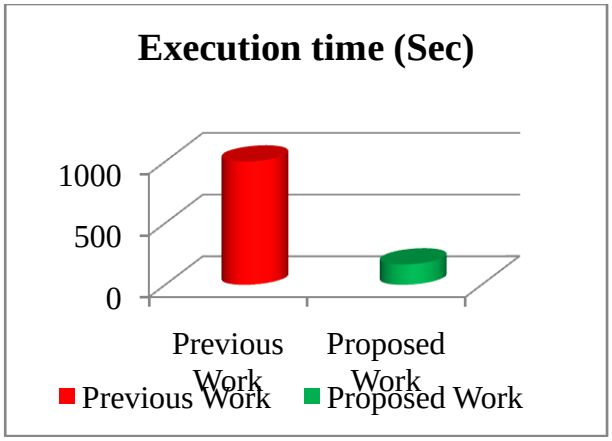

Figure 5.18: Comparison of Simulation time

This comparison graph 5.18 shows that Simulation time by previous and proposed methods. It is very significant parameter, reduced 840 sec by proposed approach. Therefore, it is clear that proposed methodology gives significant better results than previous approach.

V.CONCLUSION

The acquired outcomes will be examined and accomplish that the networks with mobile sink perform superior to that of the networks with static sink. "Energy proficiency is one of the significant issues in sensor networks. Different methodologies have been proposed for unraveling this issue. A few techniques are agent based while others are non-agent based. Agent based calculations are additionally separated into types. One is single agent based and other is multi agent-based calculation. In this paper, a short review on energy efficient calculations is introduced. These calculations are utilizing mobile agents. A few calculations are single agent based while others are multi agent based". The proposed procedure utilizes Joint Clustering Approach in which two distinctive cluster strategies are blended which improved the network lifetime of the network. The future headway of the work can be greater progression should be possible in the proposed technique with the goal that network lifetime by utilizing diverse more methodologies.This paper proposed joint clustering convention approach. It considers all out recreation region 500X500 meter and nodes region taken 200, 800 during nodes reproduction. Proposed technique based on joint cluster while past methodology based on novel strategy. Network move rate or throughput is accomplished by proposed strategy is 275Kbps while past it is accomplished 250Kbps. Reenactment time is additionally diminished up to 835 Sec. The general energy utilization is 380J while past it is 1000J. In this manner it very well may be say that the proposed technique approach gives noteworthy better execution in wireless sensor network than past methodology.

REFERENCE

[1] YH. El Alami and A. Najid, "ECH: An Enhanced Clustering Hierarchy Approach to Maximize Lifetime of Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 107142-107153, 2019, doi: 10.1109/ACCESS.2019.2933052.

[2] M. A. Hossen and S. Yoo, "Q-Learning Based Multi-Objective Clustering Algorithm for Cognitive Radio Ad Hoc Networks," in IEEE Access, vol. 7, pp. 181959-181971, 2019, doi: 10.1109/ACCESS.2019.2959313.

[3] X. He, X. Fu and Y. Yang, "Energy-Efficient Trajectory Planning Algorithm Based on Multi-Objective PSO for the Mobile Sink in Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 176204-176217, 2019, doi: 10.1109/ACCESS.2019.2957834.

[4] W. He, "Energy-Saving Algorithm and Simulation of Wireless Sensor Networks Based on Clustering Routing Protocol," in IEEE Access, vol. 7, pp.

172505-172514, 2019, doi: 10.1109/ACCESS.2019.2956068.

[5] W. Osamy, A. M. Khedr, A. Aziz and A. A. El-Sawy, "Cluster-Tree Routing Based Entropy Scheme for Data Gathering in Wireless Sensor Networks," in IEEE Access, vol. 6, pp. 77372-77387, 2018, doi: 10.1109/ACCESS.2018.2882639.

[6] S. Phoemphon, C. So-In and N. Leelathakul, "Optimized Hop Angle Relativity for DV-Hop Localization in Wireless Sensor Networks," in IEEE Access, vol. 6, pp. 78149-78172, 2018, doi: 10.1109/ACCESS.2018.2884837.

[7] S. Si, J. Wang, C. Yu and H. Zhao, "Energy-Efficient and Fault-Tolerant Evolution Models Based on Link Prediction for Large-Scale Wireless Sensor Networks," in IEEE Access, vol. 6, pp. 73341-73356, 2018, doi: 10.1109/ACCESS.2018.2882389.

[8] H. Wu, F. Yao, Y. Chen, Y. Liu and T. Liang, "Cluster-Based Energy Efficient Collaborative Spectrum Sensing for Cognitive Sensor Network," in IEEE Communications Letters, vol. 21, no. 12, pp. 2722-2725, Dec. 2017, doi: 10.1109/LCOMM.2017.2758376.

[9] K. Rajeswari and S. Neduncheliyan, "Genetic algorithm based fault tolerant clustering in wireless sensor network," in IET Communications, vol. 11, no. 12, pp. 1927-1932, 24 8 2017, doi: 10.1049/iet-com.2016.1074.

[10] L. Sivagami and J. Martin Leo Manickam, "Cluster-Based MAC Protocol for Collision Avoidance and TDMA Scheduling in Underwater Wireless Sensor Networks," in The Computer Journal, vol. 59, no. 10, pp. 1527-1535, Oct. 2016, doi: 10.1093/comjnl/bxw049.

[11] A. Ray and D. De, "Energy efficient clustering protocol based on K-means (EECPK-means)-midpoint algorithm for enhanced network lifetime in wireless sensor network," in IET Wireless Sensor Systems, vol. 6, no. 6, pp. 181-191, 12 2016, doi: 10.1049/iet-wss.2015.0087.

[12] P. T. A. Quang and D. Kim, "Clustering algorithm of hierarchical structures in large-scale wireless sensor and actuator networks," in Journal of Communications and Networks, vol. 17, no. 5, pp. 473-481, Oct. 2015, doi: 10.1109/JCN.2015.000085.

[13] H. Lin, L. Wang and R. Kong, "Energy Efficient Clustering Protocol for Large-Scale Sensor Networks," in IEEE Sensors Journal, vol. 15, no. 12, pp. 7150-7160, Dec. 2015, doi: 10.1109/JSEN.2015.2471843.

[14] S. Hamed Javadi and A. Peiravi, "Reliable distributed detection in multi-hop clustered wireless sensor networks," in IET Signal Processing, vol. 6, no. 8, pp. 743-750, October 2012, doi: 10.1049/iet-spr.2011.0341.

[15] N. Gautam and J. Pyun, "Distance aware intelligent clustering protocol for wireless sensor networks," in Journal of Communications and Networks, vol. 12, no. 2, pp. 122-129, April 2010, doi: 10.1109/JCN.2010.6391368.

[16] Asaduzzaman and H. Y. Kong, "Energy efficient cooperative LEACH protocol for wireless sensor networks," in Journal of Communications and Networks, vol. 12, no. 4, pp. 358-365, Aug. 2010, doi: 10.1109/JCN.2010.6388472.

[17] L. Wang, C. Wang and C. Liu, "Optimal Number of Clusters in Dense Wireless Sensor Networks: A Cross-Layer Approach," in IEEE Transactions on Vehicular Technology, vol. 58, no. 2, pp. 966-976, Feb. 2009, doi: 10.1109/TVT.2008.928637.

[18] Z. Quan, A. Subramanian and A. H. Sayed, "REACA: An Efficient Protocol Architecture for Large Scale Sensor Networks (Corrected)*," in IEEE Transactions on Wireless Communications, vol. 6, no. 10, pp. 3846-3855, October 2007, doi: 10.1109/TWC.2007.0596402.

[19] M. Yu, K. K. Leung and A. Malvankar, "A dynamic clustering and energy efficient routing technique for sensor networks," in IEEE Transactions on Wireless Communications, vol. 6, no. 8, pp. 3069-3079, August 2007, doi: 10.1109/TWC.2007.06003.

[20] H. M. F. AboElFotoh, S. S. Iyengar and K. Chakrabarty, "Computing reliability and message delay for Cooperative wireless distributed sensor networks subject to random failures," in IEEE Transactions on Reliability, vol. 54, no. 1, pp. 145-155, March 2005, doi: 10.1109/TR.2004.842540.

[21] O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," in IEEE Transactions on Mobile Computing, vol. 3, no. 4, pp. 366-379, Oct.-Dec. 2004, doi: 10.1109/TMC.2004.41.

[22] H. Gharavi and K. Ban, "Multihop sensor network design for wide-band communications," in Proceedings of the IEEE, vol. 91, no. 8, pp. 1221-1234, Aug. 2003, doi: 10.1109/JPROC.2003.814919.

[23] S. Lindsey, C. Raghavendra and K. M. Sivalingam, "Data gathering algorithms in sensor networks using energy metrics," in IEEE Transactions on Parallel and Distributed Systems, vol. 13, no. 9, pp. 924-935, Sept. 2002, doi: 10.1109/TPDS.2002.1036066.

[24] S. Singh and C. S. Raghavendra, "PAMAS: Power Aware Multi-Access Protocol with Signalling for Ad Hoc Networks", *ACM Computer Comm. Rev.*, July 1998.

[25] K. Sivalingam, J. Chen, P. Agrawal and M. Srivastava, "Design and Analysis of Low-power Access Protocols for Wireless and Mobile ATM Networks", *ACM/Baltzer Wireless Networks*, vol. 6, pp. 73-87, Feb. 2000.

[26] A. Chandrakasan, R. Amirtharajah, S.-H. Cho, J. Goodman, G. Konduri, J. Kulik, et al., "Design Considerations for Distributed Microsensor Networks", *Proc. IEEE Custom Integrated Circuits Conference (CICC)*, pp. 279-286, 1999.

[27] N. Bambos, "Toward Power-Sensitive Network Architectures in Wireless Communications: Concepts Issues and Design Aspects", *IEEE Personal Comm.*,

pp. 50-59, June 1998.
[28] .B. Chen, K. Jamieson, H. Balakrishnan and R. Morris, "Span: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks", *Proc. SIGMOBILE*, July 2001.
[29] .L. Clare, G. Pottie and J. Agre, "Self-Organizing Distributed Sensor Networks", *Proc. SPIE Conf. Unattended Ground Sensor Technologies and Applications*, pp. 229-237, 1999.
[30] M. Dong, K. Yung and W. Kaiser, "Low Power Signal Processing Architectures for Network Microsensors", *Proc. Int'l Symp. Low Power Electronics and Design*, pp. 173-177, 1997.

