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A Novel Weighted Clustering Based Approach for Improving the Wireless Sensor Network lifetime

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ABSTRACT
Great lifetime and reliability is the key aim of Wireless Sensor Network (WSN) design. As for prolonging lifetime of this type of network, energy is the most important resource; all recent researches are focused on more and more energy efficient techniques. Proposed work is Weighted Clustering Approach based on Weighted Cluster Head Selection, which is highly energy efficient and reliable in mobile network scenario. Weight calculation using different attributes of the nodes like SNR (Signal to Noise Ratio), Remaining Energy, Node Degree, Mobility, and Buffer Length gives efficient Cluster Head (CH) on regular interval of time. CH rotation helps in optimum utilization of energy available with all nodes; results in prolonged network lifetime. Implementation is done using the NS2 network simulator and performance evaluation is carried out in terms of PDR (Packet Delivery Ratio), End to End Delay, Throughput, and Energy Consumption. Demonstration of the obtained results shows that proposed work is adaptable for improving the performance. In order to justify the solution, the performance of proposed technique is compared with the performance of traditional approach. The performance of proposed technique is found optimum as compared to the traditional techniques.
***Keywords* -** Wireless Sensor Network, Energy preserving, Weighted clustering, Network lifetime, Cluster head selection.

I. INTRODUCTION

Among different technologies, Communication technology really plays a big role in exploring human life and making world a small place. As a part of communication technology, quick growing networks are taking considerable attention in recent years. Modern techniques are serving revolution in this domain. According to the structure of network, it is categorized in two main domains wired and wireless. While, according to their utility and applications the wireless communication is also illustrated in two parts, short range or indoor communication and broad range or outdoor communication. Among them the wireless technologies are growing more rapidly as compared to the wired network.

The wireless sensor network is one of the most popular wireless networks. It is a distributed real-time system which contains all the basic computational functions inbuilt. Unfortunately yet very little work is applied in this new system and always new improvements are essential in all areas of the system [1]. Most of the earlier distributed systems are developed with limited power and fixed resources. In contrast, the designing of a wireless sensor network should be formulated, keeping in view terms and conditions, such as the systems is completely ad-hoc and works with wireless channel, have scarce power, is real-time, utilizes the sensors and actuators as interfaces with dynamically changing sets of resources; aggregate behaviour is also important there and location is very critical. Various wireless sensor networks also exploit negligible capability devices which place a further strain on the ability to use precedent solutions [2].

In this work the wireless sensor network has been investigated for finding the solution for the energy efficiency and exploring the issue to preserve energy during communication. Additionally for overcoming the gap a new solution using weighted clustering technique is proposed.

II. BACKGROUND

A more general issue in sensor network design for static network is coverage problem. In order to make it clear, let it given a set of sensors deployed in an area, required to determine if the area is sufficiently k-covered, it means every point in the target area is covered by at least k sensors, where k is a given parameter. For finding the result, the aforementioned work [3] can be taken as reference in this special case with $k = 1$. Applications requiring $k > 1$ may be needed in situations, where monitoring capability is desired for more sensitive and unpredictable environments, such as military applications. It also happens when multiple sensors are required to detect an event. For example, the triangulation-based positioning protocols [4] require at least three sensors (i.e., $k \geq 3$) at any moment to monitor a moving object. Enforcing k ≥ 2 is also desirable for fault-tolerant purpose. The article also considers the same coverage problem combined with the communication connectivity issue [5].

Unlike the static network, mobile network doesn't having the positioning problem but they have the connectivity issues [6].Therefore the key aim is to find the solution against the mobility and connectivity issues in wireless sensor networks [7]. In order to find the solution of connectivity issues in mobile network one of the essential contribution is cluster based network functioning [8]. Thus the next section provides the recent contributions which are based on clustering approaches to enhance the performance of network and reduce the losses due to connectivity issues.

III. RELATED WORK

This section provides the study of various approaches and algorithms, which have been recently developed.

From the power preservation viewpoint in WSNs, grouping of antenna nodes is a challenging assignment. Grouping method in routing procedures occupies a key position to extend the constancy phase and the lifetime of the network. Knowing the applications of WSNs in wide range and looking forward for energy efficient ways of communication in the network, Heinzelman et al [9] proposed a clustering protocol called LEACH (Low-Energy Adaptive Clustering Hierarchy), which is a clustering protocol uses random rotations of cluster heads in order to achieve equal distribution of energy among the sensors of the network. Furthermore, it cuts down the overall energy utilization by performing a load distribution to various points of the network. The authors presented evidences of its working by depicting the simulation results. They further concluded that it offers 8 times more energy efficiency in the network.

WSNs comprise a number of network sensors alternatively actuators. These are implemented at large geographical areas and often unattended. Also, requirement of energy efficiency in these networks remains as it is. Therefore, Yan Yu, Ramesh Govindan and Deborah Estrin [10] presented an energy efficient routing protocol, designed for wireless sensor networks implemented in geographical areas. They named it as Geographic and Energy Aware Routing (GEAR) algorithm that incorporates neighbour selection procedure, attentive towards energy for routing the packet towards the destination. For dissemination of the packet inside the destination region, flooding procedure is used. To demonstrate positive effects of the algorithm, they also presented simulation results and confirmed the longer energy lifetime of the network.

WSNs are different from those typical networks, in terms of energy constraints, redundancy and low rate of data and many-to-one flows. In this scenario, end-to-end routing cannot be applied. Therefore, data-centric techniques are needed here in order to have energy efficient packet dissemination by data aggregation. Into this context Bhaskar Krishnamachari, Deborah Estrin and Stephen Wicker [11] proposed a data-centric routing mechanism and demonstrated its performance in comparison with traditional networks. Basic idea of this method is to combine data coming from different sources and then remove redundancy as well as minimizing the transmissions. To this, the conclusion drawn clearly states that this routing scheme puts positive effects on source-destination placement and communication network density, on the energy costs, delay, and robustness of data aggregation.

Above mentioned technique of data-centric routing falls short in some terms. Since network these days contain large amount of data and data redundancy, it is likely that data may be dissociated from the specific node. Therefore, it becomes natural to deliver queries to the events being occurred in the network. David Braginsky and Deborah Estrin [12] proposed a novel scheme named as "Rumor Routing" for routing queries to nodes that have observed a particular network without having concern to geography or addressing method of the underlying network. It is designed to be adaptable in a variety of applications and their requirements. The authors demonstrated its working and claimed that this algorithm is capable to deal with node failure as well as supports promising delivery rate and route repair.

Imaging and video data transmission demands higher amount of energy QoS. In such cases special mechanisms of routing must be implemented with significant awareness of energy and Quality of Service to achieve efficient sensor usage. For this Kemal Akkaya and Mohamed Younis [13] projected a routing mechanism based on energy and QoS effective constraint. It considered only end-to-end delay, and using a path function least cost path is calculated for each link. A path is chosen which has least delay and maximum throughput, in order to achieve a best effort routing service. Simulation results show that our protocol consistently performs well with respect to QoS metrics, e.g. throughput and average delay as well as energy-based metric such as average lifetime of a node.

Along with the advances of internet and communication technology, mobile ad hoc networks (MANETs) and wireless sensor networks have attracted extensive research efforts in recent years. In the past, Chatterjee et al. proposed an efficient approach, called the weighted clustering algorithm, to determine the cluster heads dynamically in mobile ad hoc networks. Wireless sensor networks are, however, a little different from traditional networks due to some more constraints. Besides, in wireless sensor networks, prolonging network lifetime is usually an important issue. Tzung-Pei Hong et al [14], an improved algorithm based on the weighted clustering algorithm is proposed with additional constraints for selection of cluster heads in mobile wireless sensor networks. The cluster heads chosen will act as the application nodes in a two-tired wireless sensor network and may change in different time intervals. After a fixed interval of time, the proposed algorithm re-run again to find new applications nodes such that the system lifetime can be expected to last longer. Experimental results also show the proposed algorithm behaves better than Chatterjee's on wireless sensor networks for long system lifetime.

This section provides the details about the sensor network routing protocols that help to improve the connectivity issues and for enhancing the performance in terms of energy consumption.

IV. Proposed Work

WSNs (wireless sensor Networks) is a technology with huge potential which is mainly used in difficult sensitive environments like battlefield surveillance (in military), disaster management, combat field reconnaissance, border protection etc. where human involvement is not possible for solving any type of network related problem or improvement. In Wireless Sensor Networks, optimum utilization of energy is the most important concern, because in this type of network it is not possible to change or recharge the batteries of nodes at all. Due to this reason to prolong network lifetime is a challenging task.

In either static or dynamic WSNs, active nodes lose its energy uninterruptedly and readily because of being in continuous working state. Hence the limited energy of these nodes has been exhausted earlier which results in network failure.

In static WSNs since nodes are static, they can't change their positions and the energy of all nodes is not being used optimally. The nodes which are nearer to the target will be more active as compare to the other nodes which are far away from the target. Active node consumes more energy because they have more loads. Due to this reason limited energy of active node has been exhausted and it results into a network failure despite of remaining unused energy present in those nodes which are away from the target. So, for making the nodes again useable which was remained unused in static network, we are proposing a new dynamic cluster head based Clustering Approach for improving the lifetime of whole network.

In our proposed technique, Network has been divided in different clusters. Each cluster posses some nodes. For each cluster one random node is being selected as CH (Cluster Head). Due to the mobility of nodes, single node is not bound to work as cluster head all the time, as the process of cluster head selection has been repeated after particular time interval, because of this all nodes have the opportunity to be selected as cluster head. That node is being selected as cluster head which have higher percentage of available resources and due to this rotation energy utilisation is optimum here and it helps to protect network failure by using energy available with all nodes.

In proposed dynamic WSNs approach, to select the cluster head, first we create the clusters according to the clustering method [15] and generally select those nodes which are directly connected to the randomly selected node.

After creating the cluster, our proposed technique works according to following steps for selection of better nodes on regular interval of time.

1. Node quality estimation

After completing the clustering process, five important attributes or parameter we identify, as Signal to Noise Ratio (SNR), Connectivity (c), Remaining Energy (e), Mobility (M) and Buffer Length (B) of each node. With the help of these parameters or attributes, first we estimate quality of each node and then calculated comparative weight of nodes for selection of cluster head. SNR gives the comparison between the levels of the desired signal to the levels of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. The node sends a data packet to neighbour node and between both the nodes during the data exchange signal strength values are estimated [16]. In order to obtain the SNR for the network nodes the sender node sends the packet to receiver nodeA_signal and receiver node send acknowledge to sender nodeA_noise. During receiving the acknowledgement the sender node compute the SNR of receiver node for receiving the signal. This calculation finds that node, which performs data delivery in critical scenarios. Therefore optimal SNR ratio is less for good quality of node selection. Second attribute Connectivity facilitates to find such node which is connected with maximum number of nodes. In this type network the nodes are said to connect, which are in radio range of a node. This is sometimes also called the Degree of node. Therefore the selected node that has higher degree can communicate with greater number of nodes [17]. Further Remaining Energy is essential attribute for node service quality estimation. As nodes in WSNs, are with limited amount of energy and loses energy for sending and receiving data and for its liveliness. Therefore with the help of remaining energy, we become able to find such nodes which possess sufficient energy for better performance [18]. Another attribute of nodes in WSNs is mobility. Nodes frequently move from one place to other, in the dynamic networks. The computation of node mobility demonstrates the rate of change in their mobility pattern. If a node is less frequently changes its place, then, that node can create such group of nodes which will be connected for long time with each other. In other words the low mobile nodes are able to form more stable clusters. [19]. As far as Buffer Length is concerned. It makes us able to find better performing nodes for receiving more data. The buffer is a temporary storage that holds the information during the data exchange. If the buffer is almost full then the node will not be able to accept new coming data and that can drop the essential information. In this way free node will serve better for the network. Thus the available buffer for accepting upcoming stream is given as buffer length. During calculations the buffer length is denoted using B [20].

Therefore with the help of these five attributes we estimate quality of nodes. But, only by estimation on the basis of separate attribute we can't be able to say that which node will be most suitable to become cluster head node. So, for selection of such node there is need of combined analysis of all attributes for all nodes. And for this our next step is weight calculation.

2. Weight calculation

In weight calculation we use all five attributes, Signal to Noise Ratio (SNR), Connectivity (c), Remaining Energy (e), Mobility (M) and Buffer Length (B) as discussed in first step. In a cluster, all nodes broadcast estimated value of its attributes to neighbour nodes. Then all nodes store values of attribute broadcasted by neighbour nodes, with its own attributes value, in a table available with each node known as evaluated parameters table. For this we take an example as shown in table 1 for evaluated parameters.

Table 1: Evaluated parameters

Node id	C	E	M	SNR	B
1	3	87	2	23.54	46
2	2	62	6	12.53	67
3	3	65	3	17.43	82
4	5	59	5	23.53	41

As evaluated values of all the attributes are shown in table1 for each node, but the problem here is that all attributes have not similar measurement scale because measurement unit for each attribute is entirely different from other. So, to calculate the weight it is necessary to find values of attributes at similar scale. For this, first of all we normalize the values of evaluated parameters with the help of proposed formula 1 as show below.

$$N_{value} = \frac{current\ value - minimum\ value}{maximum\ value - minimum\ value}$$

Where,

$$N_{Value} = Normalized\ value$$

Current value = value of particular attribute of given node

Minimum value=minimum value of particular attribute in the table.

Maximum value=maximum value of particular attribute in the table.

After normalizing the values of attributes given in table 1, following normalized values are obtained which are shown in table 2.

Table 2: Normalized parameters

Node id	C	E	M	SNR	B
1	0.33	1.00	0.00	1.00	0.12
2	0.00	0.11	1.00	0.00	0.63
3	0.33	0.21	0.25	0.44	1.00
4	1.00	0.00	0.75	0.99	0.00

Now for more nearer approximated values, these normalized values of attributes are factorised using the factor w_1, w_2, w_3, w_4 and $w_{5,}$ for Connectivity (c), Remaining Energy (e), Mobility (M), SNR, and Buffer Length comparatively. For constructing these factors, the random values can be used between 0-1 and it is required to have sum of these factors exactly to be 1. In other words $w_1 + w_2 + w_3 + w_4 + w_5 = 1$.For example, in a specified scenario, where the nodes having good energy, and almost they are having 100% energy, here the factor energy is less important to utilize for energy constrain thus the weight distribution can be 0.3 +0.05+0.25+0.20+0.20=1. In other case where the mobility is rare in all the nodes, the factor mobility is less important for weight computation thus that can be 0.30+0.25+0.05+0.20+0.20=1.

After that by using formula 2, we calculate final weight of all attributes of each node as given below.

$$W = w_1 * c + w_2 * e + w_3 * M + w_4 * SNR - w_5 * B$$

In order to compute final weight of normalized parameters of nodes given in table 2.

Let,

$w_1 = 0.30$

$w_2 = 0.25$

$w_3 = 0.05$

$w_4 = 0.20$

$w_5 = 0.20$

By using above assumed value of w_1, w_2, w_3, w_4 and w_5, we calculate final weight as shown in table 3.

Table 3: Weight estimation

Node Id	C	E	M	SNR	B	W
1	0.33* 0.30	1.00* 0.25	0.00* 0.20	1.00* 0.20	0.12* 0.20	0.525
2	0.00* 0.30	0.11* 0.25	1.00* 0.05	0.00* 0.20	0.63* 0.20	- 0.048
3	0.33* 0.30	0.21* 0.25	0.25* 0.05	0.44* 0.20	1.00* 0.20	0.025
4	1.00* 0..30	0.00* 0.25	0.75* 0.05	0.99* 0.20	0.00* 0.20	0.565

3. Cluster head selection

Further after weight calculation, now in order to select a head node for each cluster the next most important step is cluster head selection.

As with the help of weight calculation method, all nodes compute the weight of their neighbour nodes using a neighbour table. The example of neighbour table is shown as table (4) for four nodes defined in the figure1.

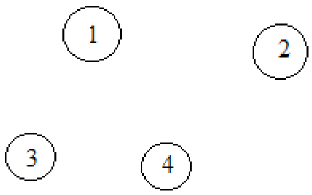

Figure 1: Sample network nodes

Table 4: Neighbour table

nodes	1	2	3	4
1	0	T	T	T
2	T	0	F	T
3	T	F	0	T
4	T	T	T	0

Figure 1 shows sample network node 1,2,3,4. Above nodes with the use of neighbour table (4), find their neighbour nodes as shown in table. In given table T represents direct connection between two nodes.

The nodes use this neighbour table to identify its neighbours and become able to broadcast its attributes to neighbour nodes and receive information about attributes broadcasted by neighbour nodes. Further nodes use this information about attributes in calculation of combined weight for all nodes with its own weight as described in detail in weight calculation method.

Thus as shown in table 3, now each node has information about weights of its neighbour nodes with its own weight, Finally cluster head selection depends on these weight information available with all nodes in a cluster. All nodes compare own weight with weight of its neighbour. If a node finds that self weight is greater than weight of its neighbour nodes then it broadcast self as cluster head. Otherwise if it finds self weight is smaller than weight of any neighbour node then it ignore self weight and update itself with cluster head information and declare self as Clint node. In rare case, there may be a situation in which weights of more than one node are optimum and equal. In such case there will be confusion in selection of cluster head. So, in this condition to deal with this confusion, further energy of equal weighted nodes is being compared. Among these nodes, that node will be selected as cluster head, which possess optimum energy.

The entire process of cluster head based clustering approach is shown below in the form of proposed algorithm.

Algorithm:

1. Start
2. Initialize set of Node in network
3. Anonymous node A initiating cluster request by broadcasting a hello packet
4. If entire node's acknowledgement is received
5. Initiate step 9.
6. Else
7. Wait for acknowledgement
8. End if
9. Broadcast SNR, C, E, M and B to first hop neighbours.
10. For each node in network
    I. Signal to noise ratio SNR
    II. Remaining Energy E
    III. Connectivity C
    IV. Mobility M
    V. Buffer Length B
    End for
11. Weight Calculation
    $$W = w_1 * c + w_2 * e + w_3 * M + w_4 * SNR - w_5 * B$$
12. Weight Comparison
    If (self-weight > neighbours weight)
    I. broadcast self as Cluster Head
13. Else if(self-weight < neighbours weight)
    I. ignore self-weight and update self with cluster head information
    II. Declare self as client node
14. Else if (self-weight=neighbour weight)
    If ($Energy_{self} > Energy_{neighbour}$)
    a. Broadcast self as cluster head
    b. Else
    c. Broadcast neighbour as cluster head
    d. End if
15. End if
16. Wait for new clustering request

The summarized steps of the algorithm are demonstrated using the flow chart of the algorithm using the figure 2. In this diagram the processes involved in the cluster head selection is demonstrated in a flow.

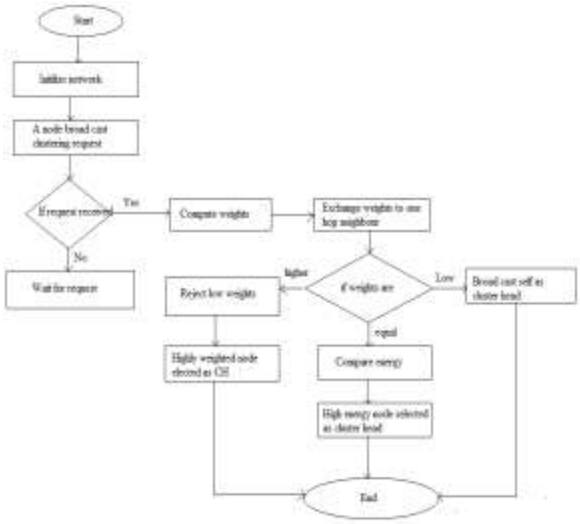

Figure 2: Algorithm flow

V. SIMULATION

The proposed cluster head selection algorithm is simulated using the NS2 network simulator. That simulation is configured on the basis of the following simulation setup and scenarios.

A. Simulation setup

This section provides the required network parameters which are used for network simulation. The key parameters and their corresponding values are reported using table 5.

Table 5: Simulation setup

Simulation properties	Values
Antenna model	Omni Antenna
Dimension	750 X 550
Radio-propagation	Two Ray Ground
Channel Type	Wireless Channel
No of Mobile Nodes	15
Routing protocol	AODV
Time of simulation	10.0 Sec.

B. Simulation scenario

This section provides the simulation scenarios on which the proposed and traditional algorithm [4] for network performance evaluation is based.

1. Simulation using the traditional approach: In this simulation a static network is prepared using the given network configuration. Additionally in this static network the issues of covering set and the performance improvement in terms of network life time is simulated. The simulation scenario is given using figure 3.

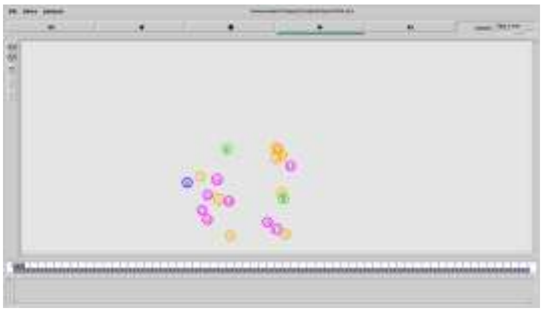

Figure 3: Traditional network

2. Simulation of proposed clustering scheme: In this scenario the proposed cluster head selection technique is implemented in the mobile network scenario and their performance improvement is provided and compared with the previous network technology. The simulation screen of the proposed simulation scenario is given using figure 4.

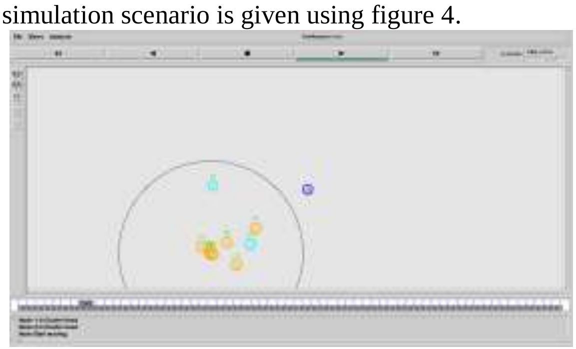

Figure 4: Proposed network

In this section the network simulation strategy is provided and further in next section the results evaluation of proposed methodology is provided.

VI. RESULTS ANALYSIS

This section provides the study of the performance parameters obtained during simulation of the proposed cluster head selection approach. Additionally the detailed description of each parameter is also reported in this section.

A. End to end delay

End to end delay is the amount of additional time consumed during communication scenario in the network, which refers to the time taken by a packet to be transmitted across a network from source to destination device, this delay is calculated using the below given formula.

$$E2E\ delay = receiving\ time - sending\ time$$

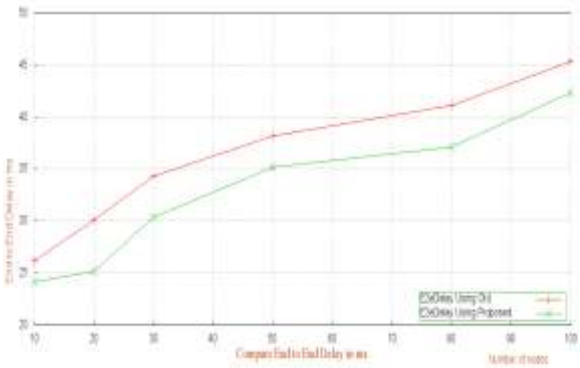

Figure 5: End to end delay

The comparative end to end delays for both the network techniques are given using figure 5. In this graph the amount of time overhead is given using Y axis, and the X axis shows the number of nodes in network. According to the obtained performance of the proposed technique, it has less end to end delay as compared to the traditional (old) technique [4]. Thus the proposed technique is much promising as compared to the traditional one.

B. Packet drop ratio

The amount of packet which is transmitted to destination node is not successfully delivered is known as the packet drop ratio. The figure 6 shows the packet drop ratio of both the techniques. In order to show the performance of network protocols the X axis contains the number of nodes in network and the Y axis shows the amount of dropped packets in terms of percentage. According to the obtained result the proposed technique drop less amount of packets as compared to the traditional technique.

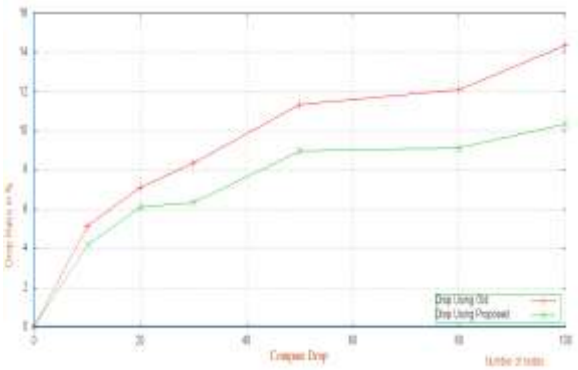

Figure 6: Packet drop ratio

C. Energy consumption

The amount of energy reduced from initial energy of nodes during the active communication sessions of network is known as energy consumption. The energy consumption is responsible to provide the efficient network life time

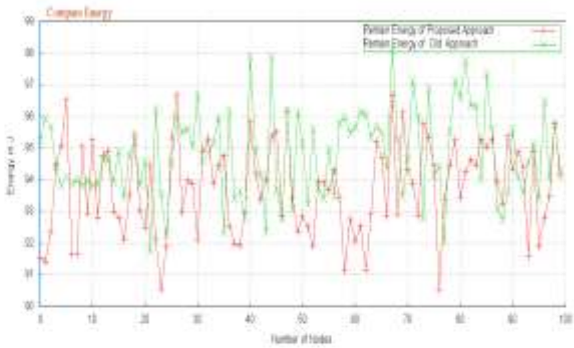

Figure 7: Energy consumption

The comparative performance in terms of energy consumption is given in the figure 7. In this graph the X axis shows the amount of nodes in network and the Y axis shows the consumed energy in terms of Jules. According to the obtained results the proposed technique consumes less amount of energy as compared to the traditional technique.

D. Packet delivery ratio

The performance parameter Packet delivery ratio sometimes termed as the PDR ratio provides information about the performance of any routing protocols by the successfully delivered packets to the destination, where PDR can be estimated using the formula given

$$packet\ delivery\ ratio = \frac{total\ delivered\ packets}{total\ sent\ packets}$$

The packet delivery ratio of the proposed and traditional network performance improvement technique is given using figure 8. In this graph the X axis shows the amount of nodes in network and the Y axis shows the packet delivery ratio in terms of percentage. According to the obtained performance the proposed technique provides higher PDR as compared to traditional technique.

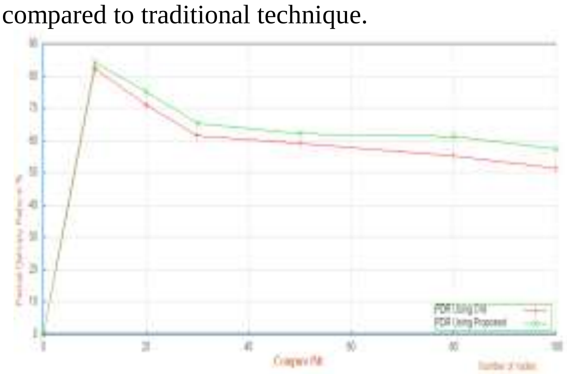

Figure 8: Packet delivery ratio

E. Throughput

Network throughput is the average rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot.The obtained performance of both the algorithms for network life time improvement is given using figure 9. In this graph the green line shows the performance of proposed technique and red line shows the performance of the traditional technique. In order to shows the performance the X axis contains the number of nodes in network and the Y axis shows the performance in terms of consumed bandwidth in terms of kbps.

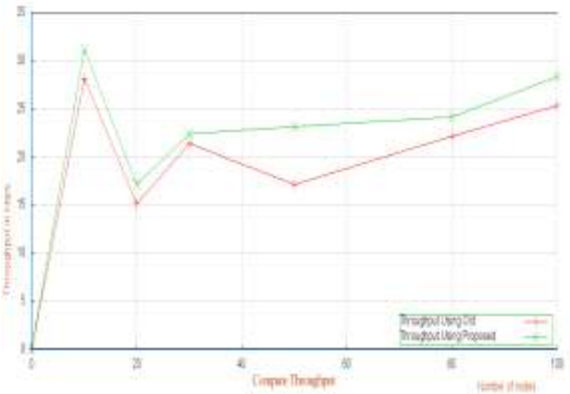

Figure 9: Throughput

This section reports the performance analysis of the proposed and traditional algorithms. Additionally their comparative performances with increasing number of nodes are presented. The next section provides the conclusion of the entire project development and the results analysis.

VII. CONCLUSIONS

In this paper, techniques are explored and studied for improving the performance of wireless sensor networks, focused on connectivity issues and energy efficiency. The cover set problem in static network is studied and their different solutions are also investigated. Further it is found that the cover set problem of static network can be converted into connectivity issue in mobile network. Therefore for optimizing the connectivity issues the clustering algorithms are studied. Among different clustering algorithms, weighted clustering algorithm is found more suitable for improving the performance of network.

Thus a weighted clustering scheme is proposed and implemented using the NS2 simulator. The given approach utilizes the network parameters to find the optimum cluster head (CH) for each cluster on regular time interval. It provides uniform load distribution to the nodes during network functioning in mobile network scenarios, results in optimum energy utilization and avoidance of network failure like situation. Furthermore the proposed clustering approach is compared with the exiting covering set solution. The performance evaluation of the proposed cluster head selection approach is provided in terms of end to end delay, packet delivery ratio, packet drop ratio, throughput, and energy consumption. According to the obtained performance the proposed cluster head algorithm consumes less energy and increases the packet delivery ratio even for the mobile networks. Thus the proposed clustering algorithm is more efficient and effective.

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