ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

An Overview on Energy-aware Clustering Technique for Maximizing Wireless Sensor Network Life Time

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Abstract

A Wireless Sensor Network is a wireless network that consists of spatially distributed devices called sensor nodes. Sensor nodes are having sensing, data processing and communication functionalities. The sensor nodes are usually programmed to monitor or collect data from surrounding environment and pass the information to the base station for remote user access through various communication technologies (network).The main aim of this paper is to propose a solution to improve the life time of the network by reducing the number of active nodes that participate in communication. Clustering technique will be proposed for increase of network lifetime greater than 44%, tremendous energy saving and reduce the energy consumption in every node in the network.

Keywords: Cluster Head (CH), Coverage, Energy saving, Increase the Lifetime, Energy efficient clustering, Wireless Sensor Networks .

Introduction

A Wireless sensor networks (WSN) are increasingly becoming the networks of choice in industrial, medical and military applications, that includes remote plant controlling, health monitoring and target surveillance [1]**.** A Wireless Sensor Network is a wireless network that consists of spatially distributed devices called sensor nodes. Sensor nodes are having sensing, data processing and communication functionalities [5].

Wireless sensor network usually has energy constrained due to each sensor node requires battery with a limited energy supply for its operation. In addition, recharging or replacing sensor battery may be inconvenient and impossible in some environments

However, the wireless sensor network should function long enough to accomplish the application requirements [2]

Therefore, energy conservation is main issues in the design of wireless sensor networks. There are different approaches to preserve energy usage and prolong the network lifetime in WSN. The key approach to improve energy usage in WSNs is the development of energy aware network protocol. This seminar presents a review of routing and clustering algorithms for energy conservation in wireless sensor networks. This seminar also present an energy-aware clustering technique for enhancing the network lifetime as well as increasing the number of successfully delivered packets and decreasing the network delay time [2]. The approach maximizes the lifetime of WSN and equally balances the total energy consumption among all nodes in the network. Figure 1 shows general wireless sensor network architecture.

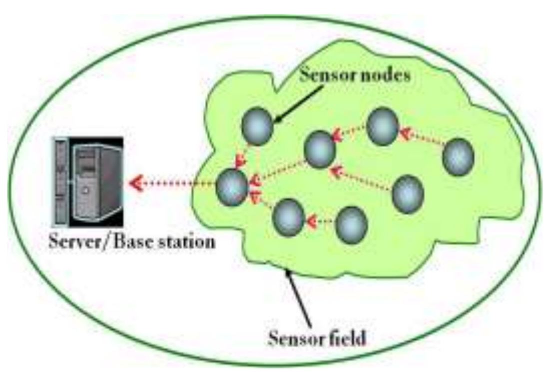

FIG.1.General wireless sensor network architecture

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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Typically, a sensor node is a small device that consists of four basic components as shown in Figure 2:
1) To Sense subsystem for data gathering from its environment,
2) To Process subsystem for data processing and data storing,
3) Wireless communication subsystem for data transmission and
4) Energy supply subsystem acting as a power source for the sensor node.

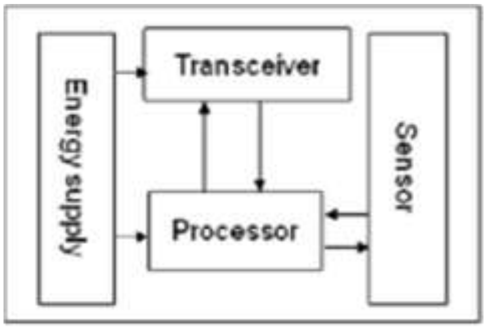

FIG.2.Sensor node components

However, sensor nodes have small memory, slow processing speed, and scarce energy supply. These limitations are the characteristics of sensor nodes in wireless sensor networks [1].

In [1], the authors present a probabilistic key pre-distribution method that allows secure deployment of WSNs. They also present node revocation and keys update techniques to ensure network connectivity and service. Efficient methods to identify cloned nodes in the network are described in [1]. Still, the lack of a common analytical frame work prevents any discussion about the degree of an attack, the network's resilience against an attack and the stability of WSNs, all of which are required to guarantee secure and reliable WSNs [4].

The energy consumed by a node depends on its state. Each node consists of two modes:
1. Active Mode (when the node keeps listening to the medium even when messages are being transmitted).
2. Sleep Mode (when the radio module is switched off, no communication will happen).

Coverage may be considered as the measure of the QoS of the sensing function for a WSN [3]. Many researchers are currently engaged in developing solutions related to coverage problems. To offer guaranteed coverage, it is essential that the coverage be solved with sufficient available resources and possibly by incorporating optimization. In the proposed approach, to reduce the energy consumption in every node in the network, we are using clustering technique [3].

In this technique, the clustering operation includes two phases: Clustering Formation Phase and Clustering Eligibility Phase. In this technique the nodes are added into group of nodes which are called cluster. For every cluster, check neighbors energy. Among the neighbors choose high energy node, announce high energy node is elected as cluster head (CH). Receiving node verifies cluster head energy with its own energy. If it is less than, convert as member. All the nodes in each cluster are supposed to convey the information to their respective cluster heads (CH) (see figure 3). Cluster head node is responsible for collecting the information, then it processes data and sends data to the base station (see figure 3).

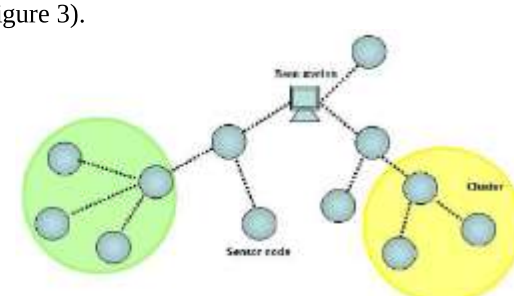

FIG.3.Cluster-based hierarchical model

Therefore, the cluster head minimize the number of active nodes, by this reduced the energy consumption in every node in the wireless sensor networks. Specifically, some nodes are active whereas the others enter sleep state so as to save the energy. Clustering technique presents an original algorithm for each node can self scheduled to decide which ones have to switch to the sleep state. Cluster head nodes may be redundant for some rounds of operation [1].

The residual energy at every node in the decision of turning off redundant nodes. Hence, the node with low residual energy has greater priority over its neighbors to enter sleep state. Significant energy savings can be achieved by sleep scheduling nodes activities in high-density WSNs. Clustering technique is one of the approaches to minimize the number of active nodes in order to maximize the network lifetime, reduce the energy consumption, provide full coverage and saving the tremendous energy. The main benefits of proposed scheme are that the energy consumption is reduced and better network lifetime can be carried out [3].

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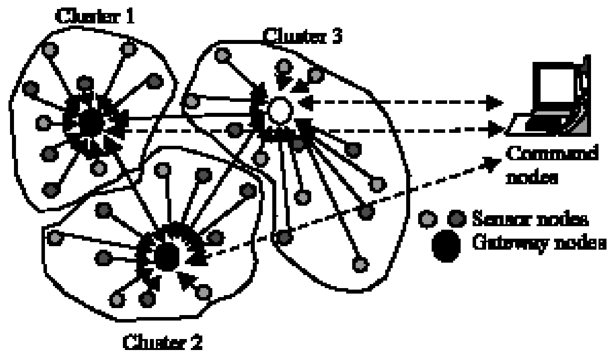

FIG.4.A cluster-head and member links in typical schemes

The advantages of cluster sampling are collection of data for neighboring elements is easier, cheaper, faster and operationally more convenient then observing units spread over a region. It is less costly than simple random sampling due to the saving of time in journeys, identification, contacts etc. When a sampling frame of elements may not be readily available [4].

A variety of improvements have been published for the last few years to limit the energy requirement in WSN, as mainly energy dissipation is more for wireless transmission and reception. Major approaches proposed so far are focused on making the changes at MAC layer and network layer. Two more major challenges are to fix the cluster heads over the grid and number of clusters in a network. To handle with all these challenges, clustering has been found to be the efficient technique [5].

The rest of this paper is organized as follows: section 2 reviews the literature review. In section 3, we introduce the details of the proposed scheme. Section 4 we discusses implementation details and presents the simulation results. Section 5 concludes the paper. At the end of the paper is a list of references.

Literature survey

Minimizing the energy consumption [6] and Maximizing the network lifetime [7] has been a major design goal for wireless sensor networks. Energy consumption is the most important design factor for sensor networks. Saving power during the operation of the electronic device could be achieved on more than one level. First, on the circuit or VLSI level, power could be saved by using less power for state transition (capacitor charging and discharging) and state maintenance. Also energy could be saved at the medium access control, and network level protocol. Minimizing the number of collisions or the path length results also in energy saving [3].

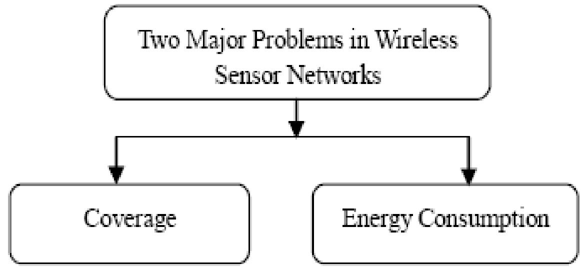

FIG.5.Hierarchy Structure of Major Problems In Wireless Sensor Networks.

Transmission and reception of radio signal is another candidate for power minimization. Short distance transmission and simple circuitry for modulation/demodulation results in power saving [10].

Many researchers are currently engaged in developing solutions related to coverage problem for wireless sensor networks. The coverage problem is subject to a wide range of interpretations. The Coverage problem [10,9] can be classified under different objectives and metrics. The different approaches to the coverage problem are centralized algorithm, distributed algorithm and configuration algorithm.

Based on the objective, the coverage problem [9] formulation varies to reflect the different assumptions and objectives. The major problems in wireless sensor networks (see Figure 5).

Some works as centralized algorithm presented in [12] propose to divide the nodes into disjoint sets, such that every set can individually and successively perform the area monitoring task. These sets are successively activated and all nodes, not belonging to the active set, will be in the sleep state. Generally, such algorithms are centralized based on a full knowledge of the network topology, which increases the cost of the algorithm. Indeed, when a node fails, the coverage is no more guaranteed despite the fact that the other nodes belonging to the same set remain working.

Centralized algorithms are not suitable for real wireless sensor networks as they induce a consequent overhead. Moreover, this entity must transmit many messages to inform each node about its schedule, which will also consume more energy. The configuration algorithm [13], must be robust despite the loss of messages. Indeed, when lost messages are not critical situations may appear. For example, the loss of deactivation messages may lead to the occurrence of blind points. Hence as the neighboring nodes have not received the deactivation message they may decide to be inactive, believing that the former node is remaining active, which introduces the occurrence of blind point. Using the same nodes to cover the area of interest exhaust their batteries. Consequently, they will fail more quickly than others, which lead to network partitioning or failure of some application functionality

The distributed algorithm presented in [15,14], involve multiple nodes working together to solve a computing problem. Using Distributed Algorithm can be designed by paying attention to the inherent dependency that exists between different cover sets since they share sensors in common. This algorithm capturing the dependencies between different cover sets, examine localized heuristics based on this dependency model and present various improvements on the basic model.

Distributed Optimum Coverage Algorithm (DOCA) which is designed to maximize the network lifetime by having the sensors periodically calculate their power to adjust their waiting time. When the waiting time expires they transition to an active state. These heuristics represent a 20-30% increase in the network lifetime, uses greedy criteria to make scheduling decisions. Previously presented works consider the ERGS algorithm [16], according to verification of its eligibility rule to minimize the energy consumption and extend the 33.33% greater than network lifetime.

TABLE NO.1.Comparison of Other References with Base Paper

Technique used	**Energy consumption**	**Robust**	**Network lifetime**
Centralized algorithm	Maximize the energy consumption	Robust	Lifetime reduced
Configuration algorithm	Energy depletion among nodes	Robust	Lifetime reduced
Distributed Algorithm	Minimize the energy consumption	Robustness	20-30% increase the lifetime
Energy Remaining Greedy Scheduling Algorithm	Minimize the energy consumption	Robustness against node failures	Full coverage and 33.33% greater than the network lifetime
Clustering Technique	Minimize the energy consumption	Robustness against node failures	Full coverage and 44% greater than the network lifetime

Thus, the Clustering Technique was introduced, for every cluster, check neighbors energy. Among the neighbors choose high energy node, announce high energy node is elected as cluster head (CH). Receiving node verifies cluster head energy with its own energy. If it is less than convert as member. All the nodes in each cluster are supposed to convey the data to their respective cluster heads (CH). By this reduced the energy consumption in every node in the network. Clustering technique is

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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one of the approaches to save tremendous energy by minimizing the number of active nodes, full coverage and prolong the network lifetime. The comparison of other references with base paper is done in table 1. The merits and demerits of reference papers and the base paper approaches are listed [3].

Proposed clustering technique

In Clustering Technique, the large numbe of sensor nodes will be divided into several clusters. For each cluster, a high energy node is selected as a cluster head. The Clustering Technique based on highest residual energy is proposed to improve the network lifetime, reduce the energy consumption in every node in the network, provide the full coverage and tremendous energy saving. In this technique, the clustering operation includes two phases: Clustering Formation Phase and Clustering Eligibility Phase. The details of these two phases are introduced as follows.

Clustering formation phase

At the beginning of the clustering formation phase, nodes are randomly deployed in large areas. Each node contains ID and its residual energy. Each node obtains the neighboring nodes information. As only the nodes within a communication range equal to sensing range are considered for the verification of the sensing area coverage. In this technique the nodes are added into group of nodes which are called cluster. For every cluster check neighbors energy. Among the neighbors choose high energy node, announce high energy node is elected as cluster head (CH). Receiving node verifies cluster head energy with its own energy. If it is less than, convert as member. All the nodes in each cluster are supposed to convey the message to their respective cluster heads. Each node can transmit its clustering message with minimum power allowing to reach this range. By this technique, minimize the number of active nodes in order to minimize the energy consumption [17] and prolong the network lifetime greater than 44% [18]. Let C be the center location for all sensor nodes. If there are n sensor nodes in the wireless sensor networks, C can be calculated by

$$C = \frac{\sum_{i=1}^{n} Xi}{n} \quad \ldots \ldots \ldots (1)$$

Where, Xi is the coordinate of sensor node i. Let R be the average distance between C and all sensor nodes, which can be calculated by

$$R = \sum_{i=1}^{n} \frac{|Xi - C|}{n} \quad \ldots \ldots \ldots \; (2)$$

According to C and R, the locations of initial mean of point $x_i(x_{ix}, x_{iy})$ for the cluster i is calculated by,

$$X_i \begin{cases} X_{ix} = R \times \cos(\frac{360}{k} \times (i-1) \times \frac{\pi}{180}) + Cx \\ X_{iy} = R \times \sin(\frac{360}{k} \times (i-1) \times \frac{\pi}{180}) + Cy \end{cases} \quad \ldots\ldots \quad (3)$$

Where k is the number of clusters and i = 1, 2... k.

Clustering Status Advertisement Message

In this phase, receiving a CSAM (clustering status advertisement message), the receiver node will compare itself to the transmitter node.

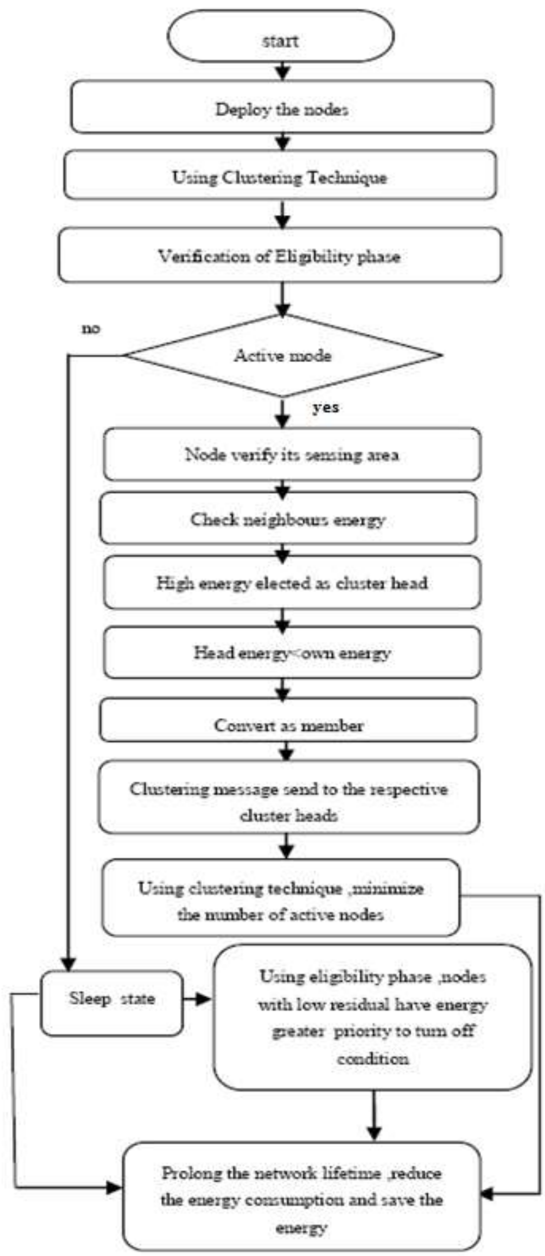

FIG.6.Flow Chart of Clustering Technique

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Based on the comparison result, the transmitter node will be added to one of two specific lists: HCS and LCS. The nodes belonging to the HCS (Receiver) list have less priority than the receiver node to be deactivated. Otherwise, the nodes belonging to LCS (Receiver) list have more priority to be deactivated. If SA(c) (sensing area) is covered, the nodes belonging to its HCS list, then it enters directly to the sleep state, where it turns off its radio and sensing units [3]. Some nodes of LCS (c) list that have already decided to be awake. The CSAM messages will not be forwarded, because nodes just need to know their neighbors [3]. The flow chart of clustering Process (see Figure 6).

In advertisement step, each node transmits to its neighbor nodes an advertisement message (ADV), including its ID and its current remaining energy [19].

- When receiving an ADV message, the receiver node will compare the current residual energy to the transmitter node. · If the current energy is higher than the transmitter node, the node is specified as HCS list. Otherwise specified into LCS list.
- The nodes belonging to the HCS list have less priority than the receiver node to be deactivated.
- The nodes belonging to the LCS list have more priority to be deactivated.

Clustering eligibility phase

After finishing the clustering formation phase, each node decides its eligibility to turn itself off. The clustering technique introduces the priorities between nodes. Nodes with low residual energy will have greater priority to turn off. The residual energy can be calculated by using equation 4.

$$\text{Overall Residual Energy} = \frac{\text{Total Residual Energy}}{\text{Total Number of Nodes}}$$

$$\text{Residual Energy} = \sum_{i=i}^{n} \frac{\text{xi(Total energy)}}{\text{(Total Number of Nodes)}} \quad \ldots \quad (4)$$

If all nodes simultaneously make decisions, blind points [16, 20] may appear (see Figure 5). Node 1 finds that its sensing area can be covered by nodes 2-4. According to the sleep scheduling, node 1 turns itself off. While at the same time, node 4 also finds that its sensing area can be covered by nodes 1, 5, 6. Believing node 1 is still working, nodes 4 turn itself off too. Thus, a blind point occurs after turning off both nodes 1 and 4.

The blind point could be avoided if only node 4 or node1 has considered the other one to the verification of priority. Thus, it is easy conclude that any two neighbor nodes simultaneously consider themselves. To achieve this objective, a notion of priority must be introduced between nodes. This priority avoids the use of additional messages and allows remaining robust despite the loss of messages while ensuring the avoidance of blind points.

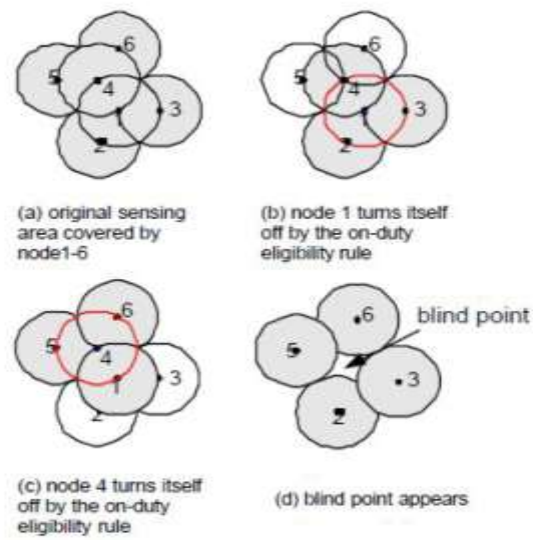

FIG.7.Blind Points Appear

TABLE NO.2. Clustering Operational Phases

Processing phases	**Tasks Performing phases**
1.Clustering formation Phase	All parts of the sensor are fully powered. Sensor performs sensing the environment, processing, receiving message from cluster head. This phase extend the network lifetime greater than 44% and reduce the energy consumption.
2.Clustering Eligibility Phase	It is energy saving phase

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Simulation results and performance analysis

In this section, we evaluate the performance of proposed Clustering Technique proposed by Sangeetha S and Ramalakshmi K using a simulation model[3]. We describe simulation model and illustrate the simulation results, and compare proposed scheme with Energy Remaining Greedy Scheduling Algorithm. Simulations can be performed using software such as OPNET, NetSim and NS2 and it is the most common method of validation. Simulations can provide a close approximations to the real behavior of a protocol under various scenarios. We design a simulation environment by using NS2 software. The assumptions for simulation study are as follows. Figure 8 shows the total network average energy when the number of sensor nodes is 100 and the sensing area is 100 m × 100 m. It is evident that the residual energy of proposed CT scheme is higher than that of ERGS. This is because proposed CT scheme provides the better lifetime and reduce the energy consumption. The data transmission distance from each sensor node to its cluster head node is minimized. Thus, the energy consumption is saved. The overall Energy consumption can be calculated by,

$$\text{Total Energy Consumption} = \frac{\text{Total Energy}}{\text{Total Number of Nodes}}$$

The energy consumption model determines the sensor lifetime. The energy calculation for a single cycle is done by using the following equation 5 in fig 8.

$$E_{cycle} = E_D+E_S+E_T+E_R \ldots\ldots (5)$$

Where E_D, E_S, E_T and E_R represent the energy required for data processing, sensing, transmitting and receiving per cycle time, respectively. The quantity of energy spent for each operation depends on the network.

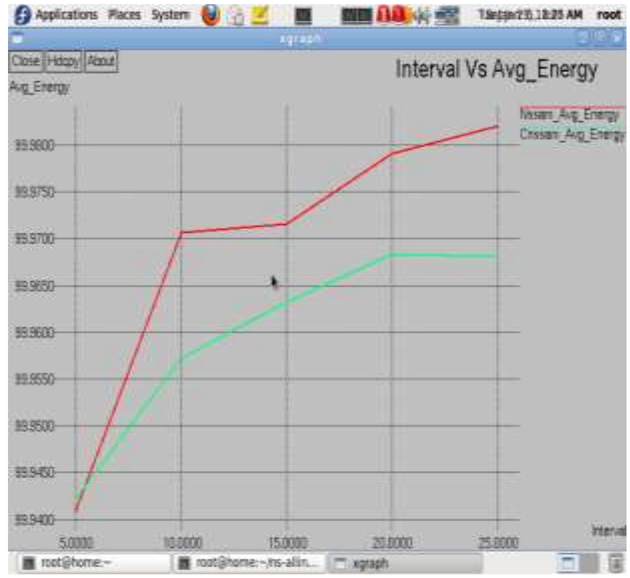

FIG.8.Minimize the energy consumption

When we compared proposed scheme with the ERGS, as shown in the fig 9, fig 10. our scheme shows, high energy node elected as cluster head. All the nodes in each cluster are supposed to convey the message to their respective cluster heads .By this minimize the number of active nodes, to reduce the energy consumption and increase the lifetime.

In this proposed approach, less energy consumption could be achieved by transmitting packets directly to cluster head toward the BS through the shortest paths and considering the remaining energy of the nodes to balance energy among the nodes in fig 8 and fig 9.

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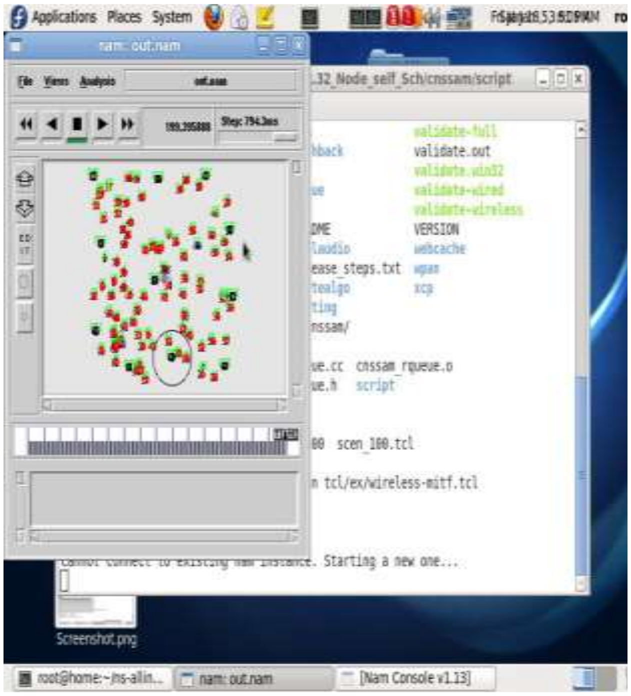

FIG.9.All the nodes in each cluster are supposed to convey the message to their respective cluster heads

FIG.10.Extension Of Network Lifetime

Packet Delivery Ratio (PDR) is the ratio of the number of data packets delivered to the BS to the number of packets generated by the source nodes as below:

$$PDR = \frac{\text{Total number of packets received at BS}}{\text{Total packets sent}}$$

Total packets sent =

$$\sum_{i=1}^{n} \text{Number of nodes}$$

$$* \text{ Number of packets sent by each node.}$$

FIG.11.Compare between ERGS and Clustering technique, increase the lifetime.

Conclusion & future scope

This paper reflects an overview on a Clustering Technique, which can reduce energy consumption, energy saving and therefore increase system lifetime, by minimize the number of active nodes. This paper presented a basic phases for clustering formation phase and clustering eligibility phase. Clustering formation Phase, minimize the energy consumption and extend the network lifetime greater than 44%. Clustering eligibility phase, based on priority of nodes. Nodes with lowest residual energy have greater priority to turn off condition. This phase saving the energy. Clustering technique is one of the approaches to provide full coverage, increase the lifetime, saving the energy and reduce the energy consumption.

Finally, several additional issues should be further studied in future research. Some of the most challenging of these issues include the development of a generic method for finding the optimal number of clusters in order maximize the energy efficiency, the estimation of the optimal frequency of CH rotation/reelection to gain better energy distribution, however, keeping the total overhead low, the efficient support of nodes and CHs mobility as well as the support of mobile sinks, the incorporation of several security aspects (i.e., enhanced protection needed in hostile environments when cluster-based protocols are used), the further development of efficient recovery protocols in case of CHs failure, etc

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