Energy Efficient Constant Cluster Node Scheduling Protocol for Wireless Sensor Networks

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Abstract: - The Wireless sensor network (WSN) consisting of a large number of sensors are effective for gathering data in a variety of environments. Since the sensors operate on battery of limited power, it is a great challenging aim to design an energy efficient routing protocol, which can minimize the delay while offering high-energy efficiency and long span of network lifetime. In this paper, we first completely analyzes the basic distributed clustering routing protocol LEACH (Low Energy Adaptive Clustering Hierarchy), then proposed a new routing protocol and data aggregation method in which the sensor nodes form the constant cluster and the cluster-head elected based on the residual energy of the individual node calculation with constant clustering and the node scheduling scheme is adopted in each cluster of the WSNs. In the node scheduling scheme (ACTIVE and SLEEP mode) the energy efficiency is increased near to 50% than LEACH protocol and lifetime of the networks also increased. Simulation results using MATLAB are shows that the proposed routing protocol significantly reduces energy consumption and increase the total lifetime of the wireless sensor network compared to the LEACH protocol.

Key-words: - Constant cluster, energy efficiency, LEACH protocol, node scheduling, network lifetime, wireless sensor networks.

1. Introduction

Wireless sensor network (WSN) consists of small in size sensor nodes, which form an ad-hoc distributed sensing [1] and data propagation network to collect the context information on the physical environment. WSN is widely used to collect reliable and accurate information in the distance and hazardous environments, and can be used in National Defense, Military Affairs, Industrial Control, Environmental Monitor, Traffic Management, Medical Care, Smart Home [2]-[4] etc.The sensor whose resources are limited is cheap, and depends on battery to supply electricity, so it's important for Routing to efficiently utilize its power in both military and civilian applications such as target tracking, surveillance, and security management. The sensor node has four basic components: sensing unit, processing unit, radio unit, and power unit. With their capabilities for monitoring and control, the sensors are expected to be deployed in vast area.

The main applications of sensor network is to periodically gather data from a remote terrain where each node continually senses the environment and sends back the data to the Base Station (BS) for further analysis, which is usually located considerably far from the target area. The most restrictive factor in the lifetime of wireless sensor network is limited energy resource of the deployed sensor nodes. Because the sensor nodes carry limited and generally irreplaceable power source, the protocols designed for the wireless sensor networks must take the issue of energy efficiency into consideration. Also, the network protocol should take care of other issues [5] such as self-configuration,

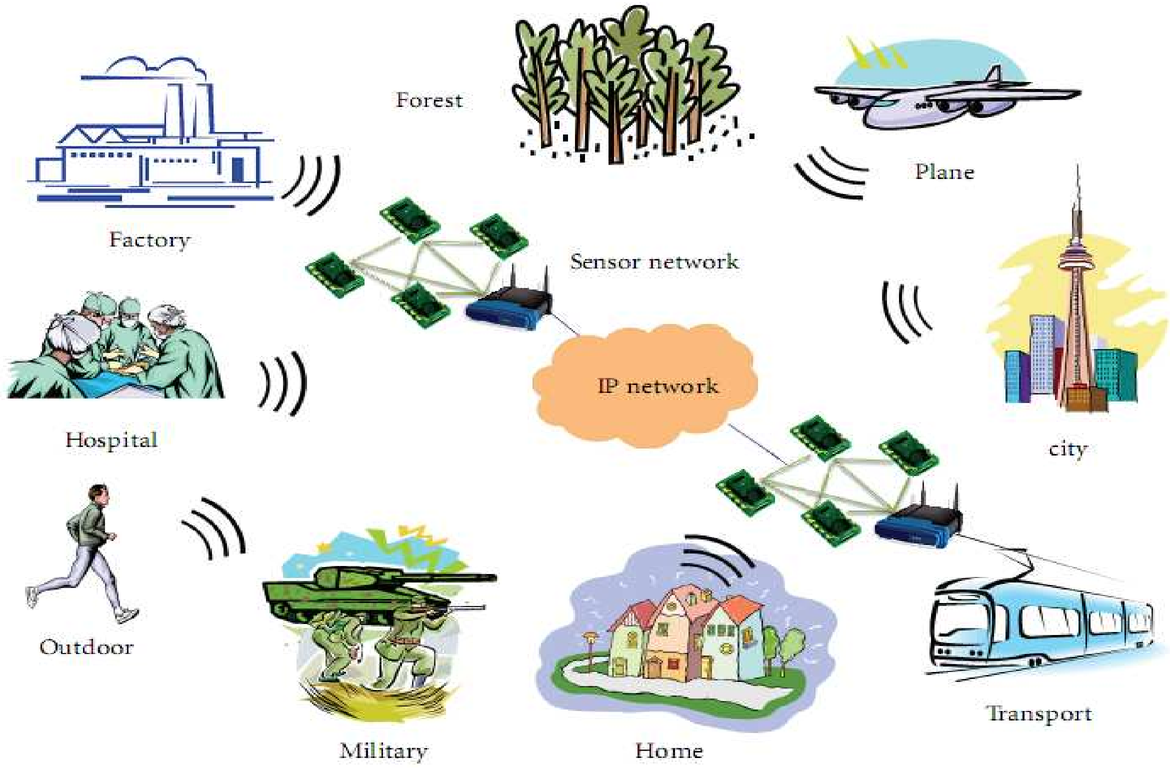

Fig.1 Application area of WSNs

fault tolerance, delay, etc. Another important criterion in the design of a sensor network is data delivery time since it is critical in many applications including battlefield and medical/security monitoring system fig.1Such applications require receiving the data from sensor nodes within some time limit. Communication protocols highly affect the performance of wireless sensor networks by an evenly distribution of energy load and decreasing their energy consumption and thereupon prolonging their lifetime. Thus, designing energy efficient protocols is crucial for prolonging the lifetime of wireless sensor networks [24, 25]. So, we described a novel energy efficient and lifetime increased proposed protocol as enhanced from normal LEACH protocol. The remainder of this paper we introduce a novel fixed clustering based data gathering approach which is having the node scheduling of active and sleep nodes in each cluster at a period of time in the wireless sensor networks to increase the lifetime [26,27] with total energy consumed.

The paper is organized as follows: A brief introduction with related works of LEACH protocol is presented in Section II. In Section III describes the design of our novel proposed protocol in detail. Simulation and results are discussed in Section IV. Finally, conclusions with future works are made in Section V.

2. Related works

2.1 Power management of radios

Power management of radios has been important issues since wireless communication is a major power consumer during system operation. One way of characterizing the importance of this problem is the radio of the energy spent in sending one bit of information to the energy spent in executing one instruction. While it is not quite fair to compare this ratio across nodes without normalizing for transmission range, bit error probability, and the complexity of instruction (8bit versus 32 bit), the radio is nevertheless useful [14]. The power consumed by a radio has two main components, (1) an RF component that depends on the transmission distance and modulation parameters and (2) an electronics components that accounts for the power consumed by the circuitry that performs frequency synthesis, filtering, up-converting, etc. Radio power management is a nontrivial problem, particularly since the well-understood techniques of processor power management may not be directly applicable. For example, techniques such as dynamic voltage and frequency scaling reduce processor energy consumption at the cost of an increase in the latency of computation. In the case of radios, however, the electronics power can be comparable to the RF component that vanes with the transmission distance. Therefore, slowing down the radio may actually lead to an increase in energy consumption. Other architecture specific overheads like the startup cost of the radio can be quite significant, making power management of radios a complex problem [15].

2.2 The Current Issues related to Energy Efficiency

There have been many attempts to address an energy efficiency problem of wireless sensor networks.

2.2.1 Power Control Capability

At the network layer, most works on the power control problem are comprised of strategies to find an optimal transmitter power to control the connectivity properties of the network [13, 14]. A common theme in these strategies is to formulate a power control as a network layer problem and then to adjust each nodes transmission power so that a different network connectivity topology can be achieved for different objectives. This approach is difficult to find optimal transmitter power of each sensor nodes.

2.2.2 Power-Aware Routing

Most schemes use a shortest path algorithm with a power-based metric, rather than a hop-count based metric. Singh et al., made some suggestions on developing a metric for power-aware routing, including energy consumed per-packet, time to network partition, variance in battery life of nodes, cost per packet, and node cost [15] . In [16], a localized routing algorithm based on the node’s lifetime and distance-based power-metrics, with the aim of extending a node’s worst-case battery lifetime have been studied. However, an energy-aware routing does not ensure good performance in energy efficiency. Use of the most energy-efficient routes may still result in premature depletion of energy at certain nodes, which is not optimal in energy efficiency.

2.2.3 Maximum Network Lifetime

The relevant works on network lifetime definition is centered on area coverage and is consistent with [17, 18].In [19], they attempted to develop a bound for the maximum network lifetime through the notion of role assignment, which corresponds to the single-session solution. Their approach is prohibitive complex problem formulation, and polynomial solutions only existed for very simple scenarios. In [20], GE’ITREE algorithm was proposed for a single-session solution based on the previous results. This proposed algorithm uses the results from graph theory, without exploring some unique properties for these networks. This approach is consequently rather complex solution compared to prior results.
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2.3. Static Clustering Protocol

In this protocol, the sensor nodes from the entire network is shown in fig. 2, are divided into several clusters, cluster-head nodes communicate with the local base station, then the local base station feed data to the entire network of base stations, and terminal user can access useful information.

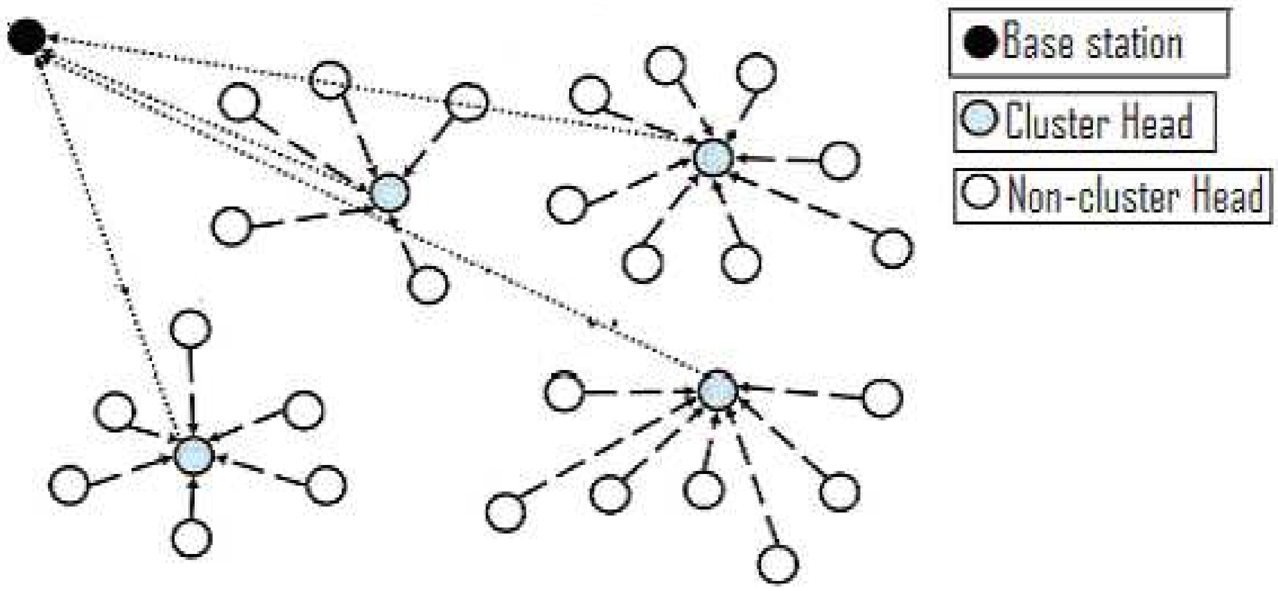

Fig.2LEACH Protocol

The distance between the local base stations and the cluster node was very close, therefore greatly reducing the energy consumption of these nodes send their information to local base station. The sensor node block diagram is given in fig 3.

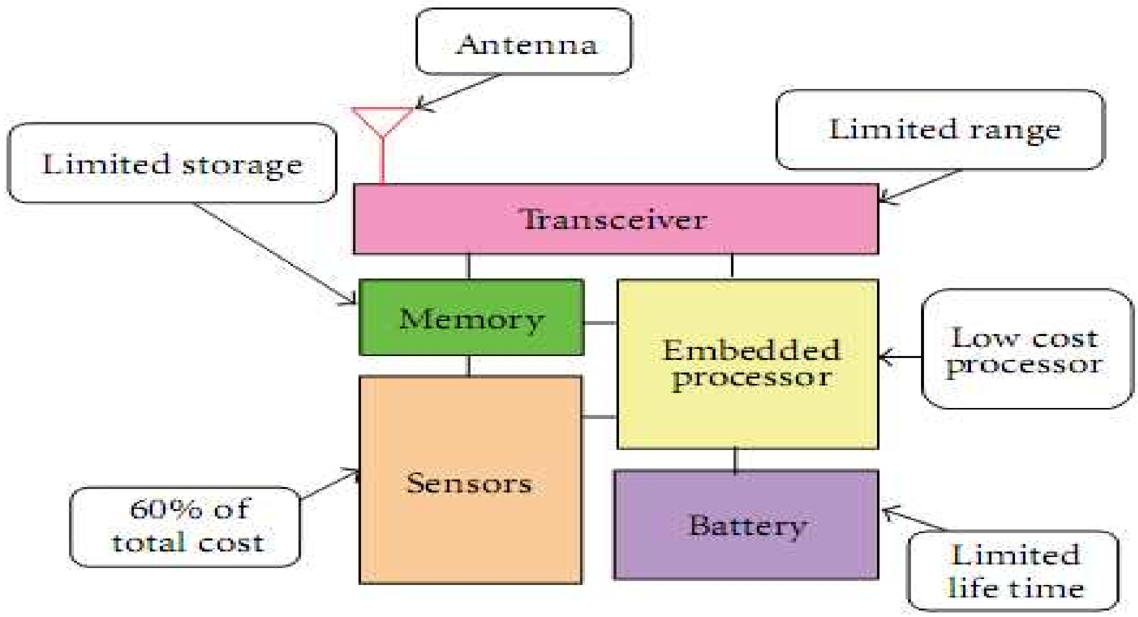

Fig.3 Block Diagram of Sensor node

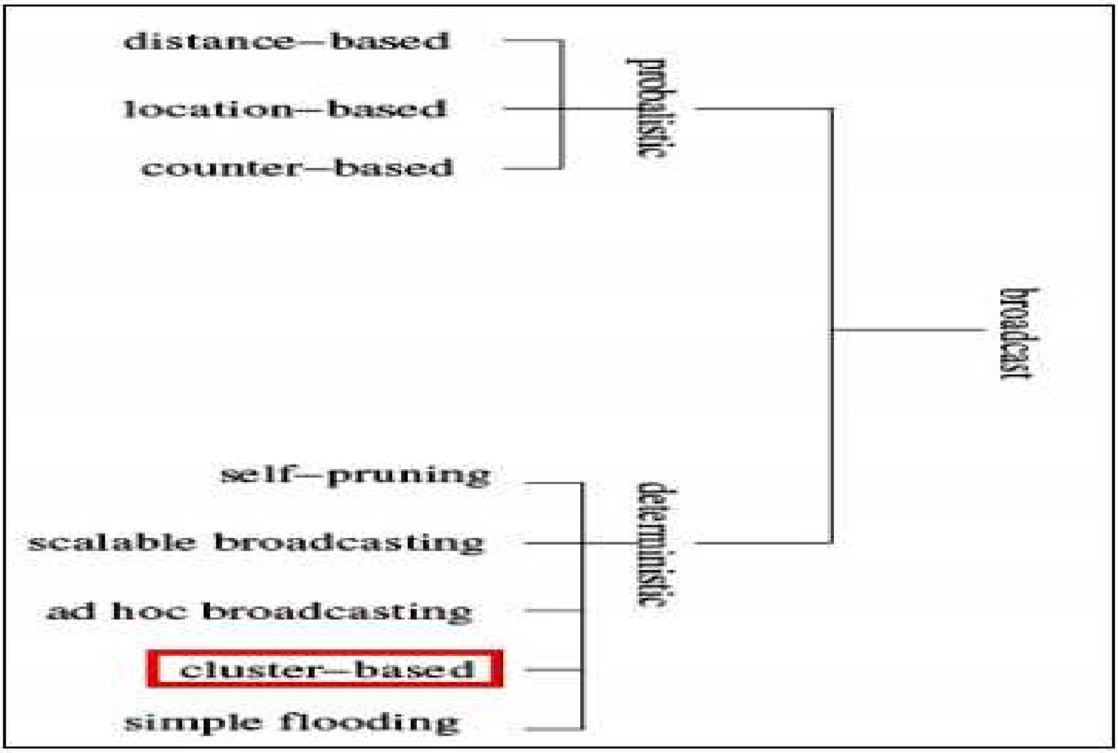

Fig.4 Broadcasting Methods

In view of this, the broad casting methods are given in fig 4 and static clustering protocol seems to be a more efficient communication protocol [6]-[9]. However, in the entire network life cycle, these clusters and cluster-head nodes are fixed, and the local base station is assumed as a high-energy nodes situation. In most cases, the local base station is an energy-constrained node. The entire network may die soon because of excessive using about local base station node.

2.4 Low-Energy Adaptive Clustering Hierarchy Protocol (LEACH)

LEACH, which was presented by Heinzelman in 2000[10], [11] is a low-energy adaptive clustering hierarchy for WSN. The operation of LEACH can be divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady state phase where several frames of data are transferred form the nodes to the cluster head and on to the base station. During the set-up phase, each sensor node tries to select itself as a cluster head according to probability model. Fig.5demonstrates the LEACH protocol Phases.

Fig.5 LEACH Protocol Phases

For selecting a cluster head, each sensor node generates a random number between 0 and 1. If the number is less than the threshold T(n), the sensor node selects itself as a cluster head for current round, the threshold is presented as follows:

$$T(n) = [p/(1-p[r \bmod (1/p)])] \text{ if } n€G \quad (1)$$

$$0 \qquad \textit{Otherwise}$$

where p is the predetermined percentage of cluster heads (e.g., p = 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1/*p* rounds. Using this threshold, each node will be a cluster head at some round within 1/*p* rounds. After 1/*p* rounds, all nodes are once again eligible to become cluster heads. In LEACH, the optimal number of cluster heads is estimated to be about 5% of the total number of nodes. Each node that has elected itself a cluster head for the current round broadcasts an advertisement message to the rest of the nodes in the network. All the non cluster head nodes, after receiving this advertisement message, decide on the cluster to which they will belong for this round. This decision is based on the received signal strength of the advertisement messages. After cluster head receives all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster head creates a TDMA schedule and assigns each node a time slot when it can transmit. During the steady-state phase, the sensor nodes can begin sensing and transmitting data to cluster heads. The radio of each non-cluster head node can be turned off until the node's allocated transmission time. The cluster heads, after receiving all the data, aggregate it before sending it to the sink.

2.5 Radio Model for Energy Calculation

In this paper, we use the first order radio model. Here are some assumptions for our mechanism [12]. (1) All sensors are within the wireless communication range when they communicate with each other or with the BS. (2) All sensors have homogeneous sensing, computing and communication capabilities. (3) All sensors are randomly deployed in WSN. (4) BS is located in the center of the sensor networks and BS has infinity energy resource. (5) All sensors in the network have the same initial energy resource and dissipate their energy resource at the same rate. (6) Network lifetime is defined as the time span from the deployment to the instant when the first sensor dies (or when the entire sensors die). According to (5), all the sensors would exhaust their energy resource at the same time. (7) Both the energy dissipation of sensing data and the energy dissipation for clustering are neglected. Compared with the power consumption of CPU and Radio, the power consumption of sensor part is so small that can be neglected. Also, we suppose that all the clustering algorithms are run on the BS and no energy dissipation of clustering on sensor nodes. (8) The time span that BS collects the information from all the sensors once is defined as a round. In a round, each sensor has only one sensed data with the same packet size. (9) The sensors that receive the data combine one or more packets to produce a same-size resultant packet, and by this way, the number of data that need to send by radio is reduced. This is reasonable, because it is generally used to the scenario that there is much correlation among the data sensed by the different sensors.

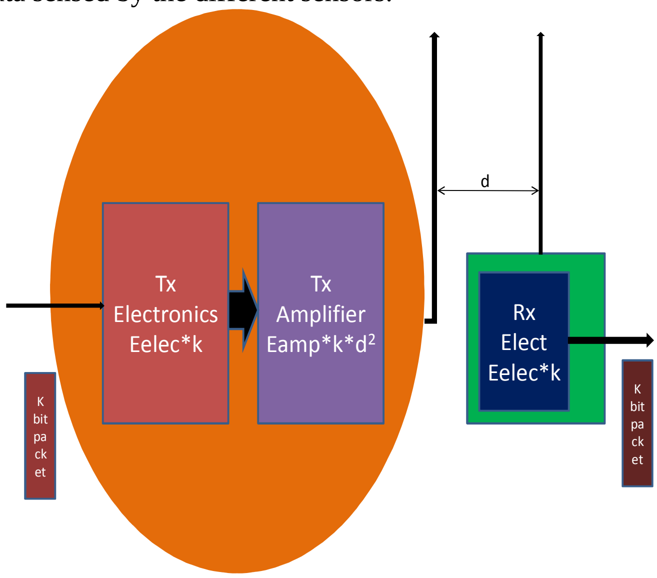

Fig.6 First Order Radio Energy Model

(10) The energy dissipation of fusing one bit data is a constant value. Therefore, the equations used to calculate transmission costs and receiving costs for a 1-bit message and a distance d are respectively shown in fig. 6.

Radio energy dissipation model adopted wireless channel models in the reference [11]. Thus, to transmit a 1-bit message a distance d, the radio expends:

$$E_{Tx}(k,d) = \begin{cases} kEelec + k\varepsilon_{fs}d^2 & d < d_o \\ kEelec + k\varepsilon_{mp}d^4 & d \geq d_o \end{cases} \qquad (2)$$

The electronics energy, Eelec, depends on factors such as the digital coding, filtering and spreading of the signal, whereas the amplifier energy, ε_{fs}, d^2, ε_{mp}, d^4 depend on the distance to the receiver and the acceptable bit error rate and d_o is a distance constant.

To receive this message, the radio expends:

$$E_{Rx}(d) = kEelec \quad (3)$$

2.6 The network initialization

The network includes some of the initial setting of energy parameters and the initialization of the sensor nodes. So it is necessary to generate a random distribution of these nodes in the L * L m^2 of the region. Random 100- node topology for a 100 * 100 m^2. Sink is located at (50, 50). Fig. 7 demonstrates the wireless sensor network initialization.

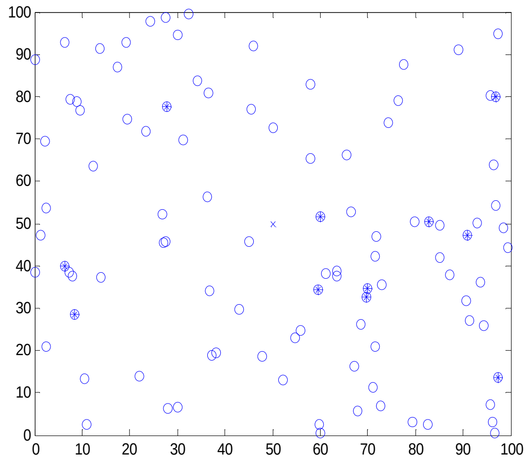

Fig.7The wireless sensor network initialization

3. Proposed Protocol

In this section we describe the proposed routing scheme which employs the node scheduling in each cluster in the network. The structure of the proposed routing scheme for wireless sensor networks is shown in fig 8. Here the same procedure as in the normal LEACH protocol is followed. By taking the number of sensor nodes shown in figure 8, the formation of the clusters is same in this proposed protocol and also the cluster head selection by comparing the residual energy of the individual in every round[13]. By doing this procedure repeatedly the total energy efficiency ultimately increased because of the proper node scheduling in cluster. In this node scheduling the total available residual energy is equally distributed and the cluster head also elected as per the residual energy comparison. Only thing is when ever the node is under sleep mode in each cluster it consumes very small energy. Here the total rounds are increased by doing both changing of sleeping and active modes and the available energy is distributed in a balanced manner.

By properly doing the node scheduling in each cluster with proper time interval, the total energy consumed is low and the total lifetime of the wireless sensor network is increased near to 50%, when compared with the normal LEACH.

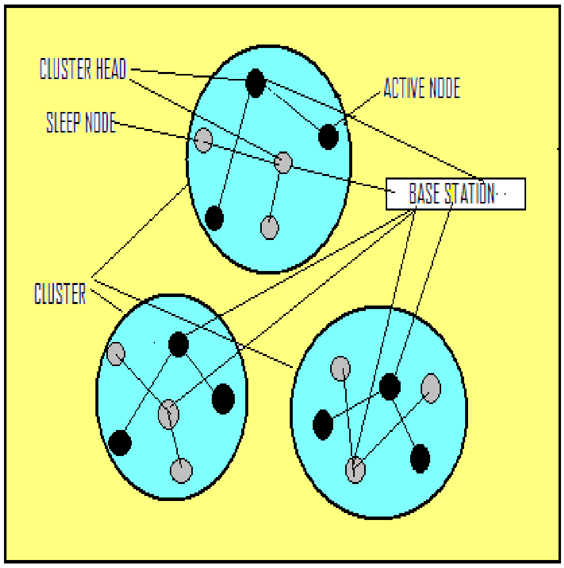

Fig.8 Proposed Protocol

4. Simulation Results

In this section, we evaluate the performance of the proposed approach through the simulations. A simulator is designed and implemented in MATLAB in order to investigate the energy efficiency with lifetime extension of the mentioned protocol. We compare the proposed protocol with LEACH protocol. The simulation parameters used in the experiment is shown in Table I. The nodes are randomly distributed between x=0, y=0 and x=100, y=100 with the base station (BS) at location x=50, y=50. The fig. 9 and 10 are shows total number of nodes that remain alive over simulation time of 700 rounds for LEACH protocol and proposed protocol. It can be seen that nodes remains alive for a longer time (rounds) in proposed protocol than LEACH. Note that further increasing of the number of nodes and the area does improve the network lifetime considerably. Based on the simulation results, we found that an energy saving up to 50% is obtainable. Using the metrics, first node dies (FND) and Half of the nodes alive (HNA) in the proposed protocol is compared with LEACH in terms of network lifetime.

Table 1

Parameter	Values
Network area	100m *100m
Number of nodes	100
Initial Energy	0.5J
BS position	50m * 50m
Eelec	50nJ/bit
Etx=Erx	50nJ/bit
ε_{fs}(friss-amp)	10pJ/bits/m^2
ε_{mp} (two-ray-amp)	0.0013pJ/bit/m^4
do=sqrt(ε_{fs} / ε_{mp})	
E_{DA}	5nJ/bit
Packet size	4000bits

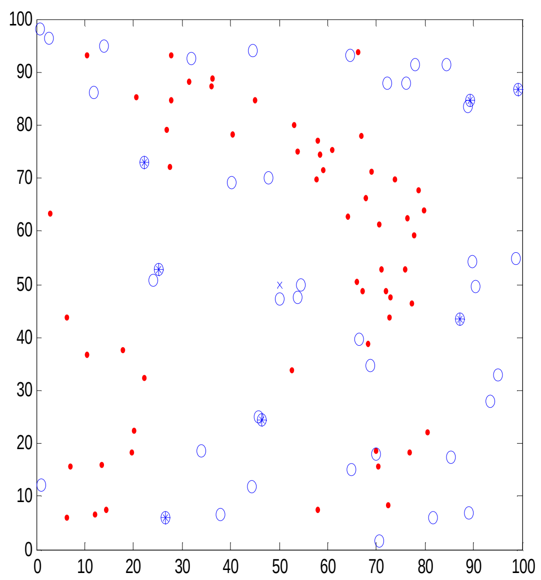

Fig.9 System lifetime using LEACH protocol after 700 rounds. Red points are indicates dead nodes (Nearly 50 nodes). Cluster heads indicated as *. Sink node is at center as ×.

Fig. 9 giving the simulation result of live nodes after 700 rounds for normal LEACH protocol. Here 50% of the nodes are lost their energy and nearly 45 nodes are in live position. When we have nearly 1500 rounds all the nodes in the network are lost their energy. But in the case of

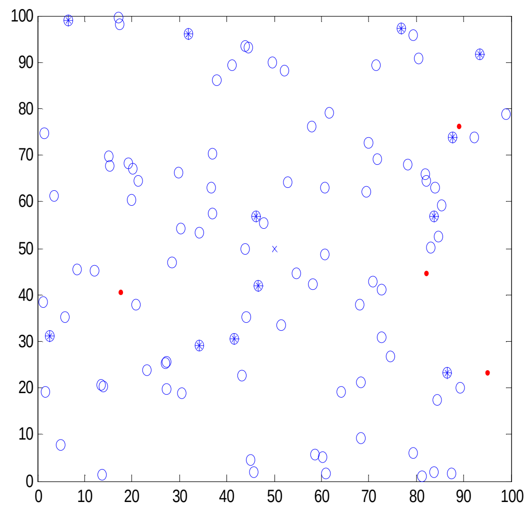

Fig.10 System lifetime using proposed protocol after 700 rounds. Red points are indicates dead nodes only nodes). Cluster heads indicated as *. Sink node is at center as ×.

proposed protocol which is in the fig. 10 giving the simulation result of live nodes after 700 rounds are 94 nodes out of 100 nodes. This is indicated in figures 9 and 10 with blue round shape color as live nodes and red points are the energy lost nodes. The proportionate numbers of cluster head nodes are indicated as *.When we increase the topology size and the number of nodes the system lifetime of the network also proportionately increased ultimately the energy also efficiently consumed.

Fig. 11 describes the comparison between the normal LEACH protocols with the proposed protocol. Here the total energy efficiency is increased nearly 50% than the Leach protocol. After 2700 rounds only the proposed protocol nodes are under dead position, but in the case of normal LEACH protocol all the nodes are lost their energy nearly 1300 rounds itself. This is clearly giving a good result of the proposed protocol.

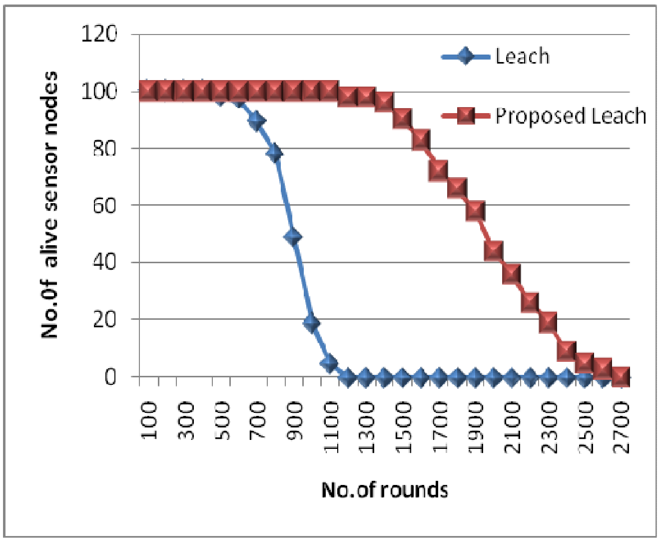

Fig.11 Total number of live sensor nodes Versus Number of rounds.

5. Conclusion and Future Works

In this paper, we have presented the proposed protocol using the proper node scheduling (ACTIVE and SLEEP) in the individual clustering of the whole network, which is an energy efficient clustering method for WSNs and compared it with the normal LEACH protocol. Results from our simulations using MATLAB are shows that the proposed protocol provides better performance in energy efficiency and increasing level in lifetime of the wireless sensor networks.

For future work, a model with heterogeneous wireless sensor nodes with its topology to have good energy efficient and increasing lifetime network may be investigated.

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