

Implementation of Smart Sleep Mechanism and Hybrid Data Collection Technique for Maximizing Network Lifetime in WSN's

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Abstract

Objectives: The main aim of this paper is to optimize energy of the wireless sensor nodes by applying hybrid data collection and smart sleep mechanism in the sensor network. **Methods/Analysis:** In energy-constrained wireless sensor networks, energy efficiency is critical for prolonging the network lifetime. The instable dissemination of communication loads often roots nodes in some region to be drained faster than the nodes in other regions. This will affect the network lifetime. **Findings:** When compared with Power-Efficient Gathering in Sensor Information Systems (PEGASIS), Low Energy Adaptive Clustering Hierarchy (LEACH) and Delay Aware Network Structure (DANS), the simulation outcomes show that proposed achieves its intention of less energy depletion, matching the energy depletion of all the nodes, alleviating the data gathering, and prolonging the network lifetime. **Conclusion/Application:** The hybrid technique prolongs the network lifetime and thus large amount of data can be easily collected by sensors and then routed to sink. In war fields or in conditions of natural disasters wireless sensor networks could be deployed with this proposed technique for maximization of network life time.

Keywords: DADCNS, Intelligent Sleep Mechanism, LEACH, PEGASIS

1. Introduction

Sensors which are efficient in computing and transmitting are extensively available with low cost^{9,20}. The deployment of these sensor nodes will collect the useful data from the deployed environment. Various types of data can be acquired from the deployed field such as temperature, audio, video etc., but the major concern of the sensor nodes is their limited energy resources, which has a direct impact on the network life time. Most of the energy of the nodes was consumed for transmitting and receiving the data. Therefore efficient communication protocols must be used to increase the network life time. Many applications of the sensor network are in the fields like where the energy resources are static and once they are embedded they cannot be re charged. So these energy resources should be used efficiently. Network lifetime is an important

parameter which tells us the time for which the network lasts i.e., the time last node got dried up. Without following the energy equalization, some nodes will soon get exhausted thereby sensing area will be decreased, which leads to the network partitioning²³. Therefore, energy consumption is very crucial point for improving the network lifetime. For this purpose there are many protocols such as the LEACH⁶ and the PEGASIS¹¹. There is a possibility of occurring delay in the network. For this, Delay Aware Network Structure is also discussed that will provide increasing number of clustering¹⁴. In addition to the above there are many other protocols and algorithms to improve the performance of the network. Finally to avoid redundancy in data collection intelligent sleep mechanisms are explained¹³. The problem of unequal usage of energy nodes is common in networks, where message traffic is unequally distributed. In LEACH⁵ random

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choice and frequent alteration of Cluster Heads (CH) for distribution of the total load into all nodes are used. The data communication in this protocol is based on one-hop communication model. Many data gathering and routing protocols in WSNs have been invented for increasing the energy efficiency in the recent time. In PEGASIS¹¹, a linear-chain scheme is nominated for all-to-all broadcasting and data gathering. Every node of the network will try to communicate with the nearest neighbouring node and in this fashion data is sent to the BS, which as a whole reduces the energy consumption. PEGASIS¹³ is regarded as an efficient method in optimising the energy and for energy equalization. However formation of chain for the data transfer from the node to the BS will introduce considerable amount of delay. This effect is more if the network size is more. Apart from the above each and every node should be aware of the location of all other nodes. In clustering method cluster members transmit data to the cluster head. At cluster head data get fused and fused data will be transmitted to a Base Station (BS), thereby reducing the energy consumption^{21,22}. However using clustering method adds extra delay to the network^{14,19}. Whenever the node is in sleep mode it consumes less energy. Here, the total rounds are alleviated by doing both switching of sleeping and active modes and the available energy is distributed in a equalized manner¹³.

2. Protocols Description

2.1 LEACH Protocol

LEACH protocol is the very first clustering technique formed in 2000² for wireless sensor network. In this protocol the nodes are divided into groups called clusters. Here, a dedicated node with enhanced functionalities called Cluster Head (CH), is responsible for producing and arranging a Time Division Multiple Access (TDMA) schedule. This CH, also sends the collected data from nodes to BS. Except CH, all other nodes are normal Cluster Member (CM). LEACH has two phases which gives rise to complete round.

They are:

1. Set-up Phase.
 - Advertising Phase.
 - Clustering Phase.
2. Steady Phase.
 - Schedule Production.
 - Data Transmission-Reception.

2.1.1 Setup Phase

Each node finalizes if it will be a CH or not. A node which is failed to be selected as CH previously has high probability to become CH. In the advertising phase, analyzing advertisement sync packet, normal nodes comes to know as CH in its cluster. After that, by examining join packets which has the identity of a node, head understands that which nodes are in its cluster area. Now the CH has the number of CM and their identity. Based on all information received from the cluster, TDMA schedule is set up by CH node and TDMA table is sent to the CM to indicate their call for sending data.

2.1.2 Steady-State Phase

Data transmission starts at steady state phase. CH gets data from the nodes at its allocated TDMA time⁷. It takes a little amount of energy. The radios of all the cluster members are turned off excluding their TDMA time. So that the energy can be conserved. After the CH receiving the data from the cluster members it will aggregate the data and forwards it to the BS. This aggregation process reduces the amount of transmitted data.

Although LEACH protocol was first to put forward the notion of energy optimization but certainly it has few shortcomings are:

- Selection of CH is random, that does not consider energy consumption.
- Due to one hop routing within cluster it fails to cover large area.
- LEACH gives no guarantee on positioning of CH nodes. CHs are not distributed evenly, but on the edges of each cluster.
- Fixed percentage of CH is 5%.

2.1.3 Delay Aware Network Structure

In wireless sensor networks with clustering method, collecting the data from the cluster member to the CH is common^{8,10}. Let 'T' denotes transmission delay for sensor nodes. All data packets sent from these nodes are correlated, and these nodes are capable to aggregate all received packets in a single packet by using data/decision fusion tricks. From the Figure 1(a), we can observe that the BS takes 3'T' to collect data from the entire network. Now from Figure 1(b), we can observe that after converting the entire network into a multi hop network time required to collect data from the network to the BS reduce to 2'T'.

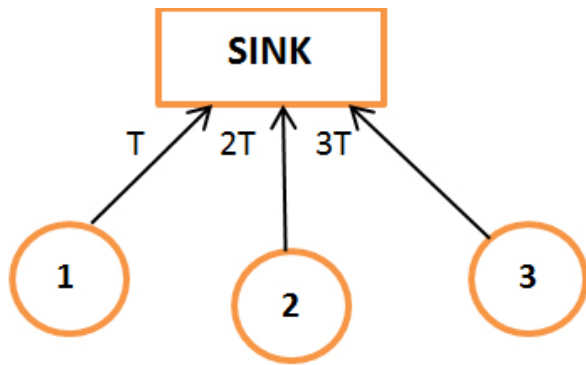


Figure 1. (a) Direct transmission to the base station.

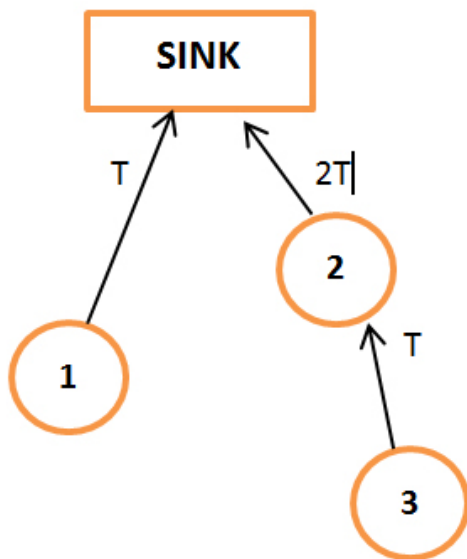


Figure 1. (b) Transmission by data fusion.

In the altered network, in addition to the shorter delay in data collection^{14,18} and while waiting for the CH to be available, the incoming information was handled by the small buffers. In addition to the above the distance between the nodes is kept as small as possible. Assume a network with N nodes, where CH required will be,

$$K_{\max} = \log_2(N) + 1 \tag{1}$$

So each CH will have 2^{k-1} nodes in its cluster. And the k th cluster will have left over nodes. All the data packets received by the nodes are correlated. Therefore all the packets are fused into one packet by fusing the data at the node. By using the proposed network structure, the number of time slots required for the BS

$$T(N) = \log_2(N) \tag{2}$$

Therefore the sum of the time slots of the CH plus 1 is the total optimum time slots required by the base station and is given by,

$$T(N) = \log_2(N) + 1 \tag{3}$$

2.1.4 PEGASIS

PEGASIS topology⁹⁻¹² is mainly based on chain architecture. Once the chain is formed a leader will be elected among the CHs. After this process before forwarding the data a token is passed to entire chain so that whichever the node receives the token will forward the data to its neighbouring node. This process continues till the data reaches the leader CH. At each and every node data aggregation will take place. Once all the information reaches to leader CH it aggregates its own data with received information. Finally it transmits to the BS. Here if every time the same node acts as a leader energy will not dissipate evenly among the network. In order to stop the fixed node being treated as CH and the hence early death of this sensor node, CH position will be taken by all other nodes in turn. Travelling sales man problem is the one which reflects the above method of forming a chain, which is known to be obstinate. With the radio communication energy values, greedy approach is the one which gives better performance by building a simple chain^{4,9}.

So following are the advantages of PEGASIS:

- Every node communicate with its neighboring node and even performs the data fusion.
- The distance between the nodes that are connected with each other has reduced considerably.
- Nodes take tries to be the CH, so it consumes zero energy.

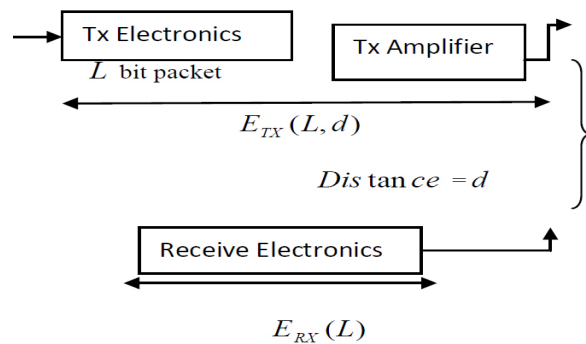


Figure 2. Transmitter Receiver model of Wireless Sensor Network.

There are some disadvantages of using PEGASIS:

- Time-delay occurs because of data transmission.
- There is more probability of forming a long chain because of the greedy approach.
- The CH selection is not suitable for load balancing.

The PEGASIS gains between 100 to 300% enhancement when 1%, 20%, 50% and 100% of nodes run out of energy as compared to the LEACH protocol.

2.1.5 Sleep Mechanism

This protocol acquires the ISM for sensor nodes in the network by examining the data transmitted by nodes, reckoning on this data clusters are either elected to perfect data sending in and around or are switched to sleeping style until the next upcoming round¹³. Nodes in this sleep mode cannot sense any data throughout the round. This smart scheme is a new scheme for finalizing nodes in the sleeping mode, all previous protocols using the sleeping style for motes did not consider the calibre of data sent as packets are missed after finalizing the sleeping mode.

Most of them depended on the number of neighbouring nodes and thus the expectation of redundant data. Using the intelligent scheme, the initial data packet of all live nodes in network is examined intelligently to bear whether the consequent packets in given round is of importance or not¹³. Therefore, the ISM is a trick that adds QoS (Quality of Service) to proposed algorithm and increases its lifetime depending on the decision upon this analysis. A typical layout of network is shown in Figure 3 where some clusters are made to sleep and half of clusters are operating and transmitting data. The BS employs the ISM on the first packet to see whether next packet from that cluster should be taken or dropped.

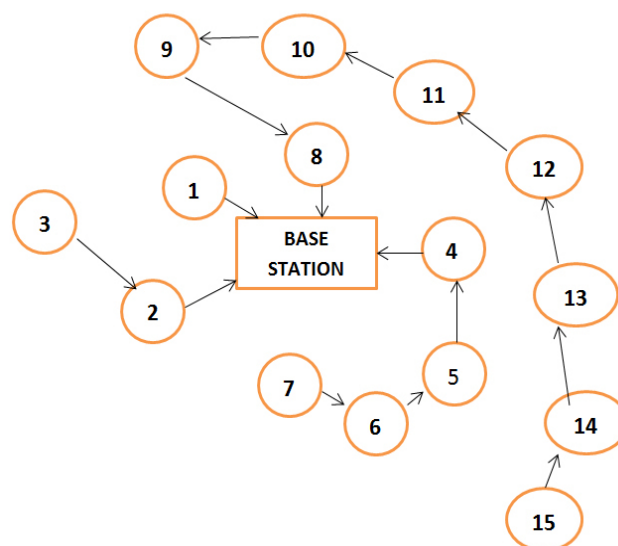


Figure 3. Network Connection.

Table 1. Energy values

Sl. No.	Energy Values
1.	Energy given to all nodes E_0 0.5J
2.	E_{TX} & E_{RX} transmitter/receiver energy 5×10^{-4} J
3.	E_{fs} 10^{-11} J
4.	E_{mp} 1.3×10^{-15} J

4. Radio Model

The received signal power of individual packet is predicted by free space model¹. The free space model considers a line of sight between transmitter and receiver. The following equation gives the received signal strength at a distance of d from the transmitter and the values as in Table 1.

$$Pr(d) = \frac{P_t G_t G_r \lambda^2}{4\pi d^2 L} \tag{4}$$

Here, P_t denotes the transmitted signal power; P_r denotes the received power, G_t and G_r are the transmitters and the receivers antenna gain, respectively. L is the loss factor of the system and λ is the wavelength of the signal that was transmitted^{11,17}. The first order radiomodel shown in Figure 2.

$$E_{TR}(m, d) = m * E_{elec} + k * E_{fs} * d^2 \quad (d < d_0) \tag{5}$$

$$E_{TR}(m, d) = m * E_{elec} + k * E_{fs} * d^4 \quad (d > d_0) \tag{6}$$

3. Network Model

3.1 Assumptions

In this paper a network of N nodes are considered and are randomly distributed over a region and the BS is located inside of the network. Some of the assumptions for the network are as follows:

- Every node is capable of sensing to the BS.
- All the nodes and BS are static.
- Location of BS is far away from the sensing arena.
- The network considered is homogeneous.

The energy dissipated by the radio in receiving a message is given in equation (7).

$$E_{TR} = m * E_{elec} \tag{7}$$

where, E_{TR} is the unit energy dissipation for electronic transmitter or receiver. E_{fs} denotes amplifier energy while E_{mp} is the multipath energy consumption in the model.

$$do = \left(\frac{E_{fs}}{E_{mp}} \right)^{0.5} \tag{8}$$

The energy consumption per unit for transmitter or receiver is defined as $E = 50$ nJ/bit, which a radio dissipates to run the transmitter or receiver circuits^{15,16}.

5. Proposed Algorithm

The focus is completely on maximizing the network lifetime. For this distributed consumption of energy is very important factor. The election of CH is crucial to improve the lifetime and remaining energy of the network^{12,19}. The node with highest energy compared with the other nodes will be the CH for that round. The uniform threshold equation for LEACH is given by¹⁶.

For n^{th} round 'Temp' will be generated where $p = 0.05$,

$$\text{Temperature} = \frac{p}{1 - p * \text{mod}\left(n, \frac{1}{p}\right)} \tag{9}$$

From the above equation the nodes analyse the threshold value and compares with the random value generated between the limits 0 and 1. A node will be eligible to become CH, if the threshold value of it is more than the random value^{21,22}.

After selection of k CHs the least 2^{k-1} nodes are elected as their CM and thus clusters are made in increasing power of 2. Once cluster is formed, each cluster forms a single chain and routes data into it^{22,23}. As shown in Figure 4 there are 15 nodes, $\log_2(15)$ approximately 4 so there will be 4 cluster heads nearest to the base station. Now to these 4 nodes other cluster members will be associated depending on the 2^{k-1} . The connected chain looks like this.

Using sleep mechanism^{3,13} divide into 2 groups A and B and carry out the routing procedure as mentioned above. Even number of rounds group B will be switched off: For odd number of rounds the network will look like, group A will be switched off.

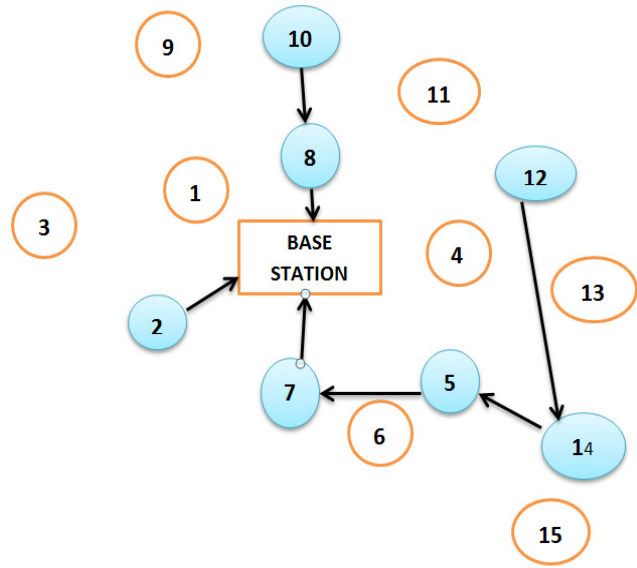


Figure 4. Group 'A' is switched on.

After each round analyse the dead nodes i.e., energy level 0J and thus route again with live nodes left in the network. This network is very adaptive, it recalculates number of CH required and new topology is set up every time on the basis of live nodes. So, energy balancing is achieved²⁰.

6. Algorithm in a Nutshell

- Fix the base station at center of the area and distribute nodes in given area with some fixed energy of 0.5 nJ.
- Based on the distribution and distance from base station divide entire network in two groups 'A' and 'B'.
- When even rounds are going on switch off group 'A' nodes and when odd rounds switch off group 'B' nodes.
- Now find out optimal number of cluster heads needed using formula $\log_2(n) + 1$, where n is the amount of nodes.
- After election of k cluster heads the nearest 2^{k-1} nodes to k^{th} cluster head is assigned to them.
- Transmission of data is done from cluster members to cluster heads in first round, from second round onwards base station pays attention to the data sent in next coming rounds.
- If same data is being sent by the x percentage of cluster members then base station switch offs the entire cluster for next round.
- Repeat this steps until all energy of the network is down.

7. Simulation Results

The performance of the proposed algorithm is assessed using MATLAB 10a simulator. The 200 WSN nodes were randomly distributed in a spatial region of 200m × 200m network area and the simulation is carried for 4500 rounds. The Figure 5 shows group 'B' is switched on.

Number of live nodes: The lifetime of the nodes decides the performance of a network, the performance of the network will be more if the lifetime of the nodes is high. Figure 6 shows the comparison of 4 algorithms the proposed one, LEACH, PEGASIS, DADCNS among which proposed goes for the 4434 rounds while PEGASIS goes for 2223 rounds and LEACH and DADCNS are at 1000 rounds.

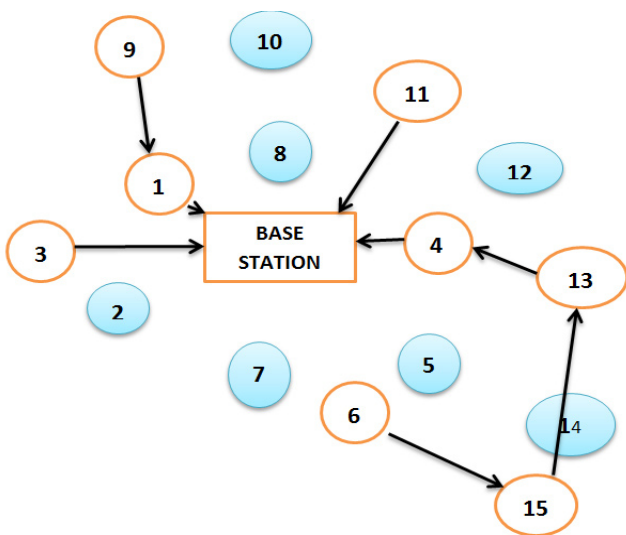


Figure 5. Group 'B' is switched on.

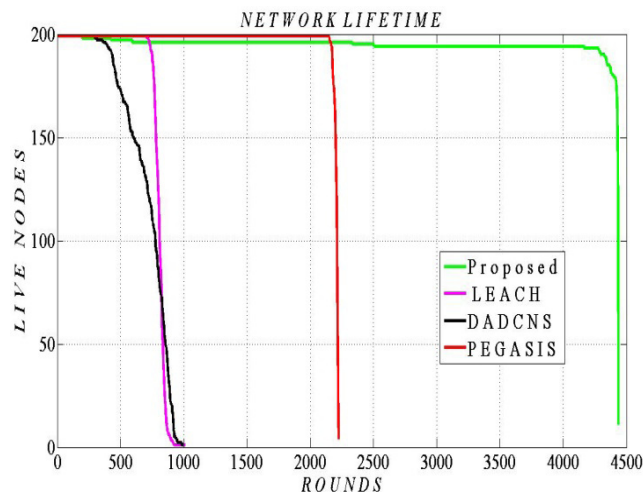


Figure 6. Network lifetime for 200nodes and 200 x 200m².

The Figure 7 when we increase the area of the network to 600m x 600m keeping same number of nodes i.e. 200, the graph looks like fig LEACH runs out of energy at 115 round while DADCNS goes upto 1942 rounds, PEGASIS 2217 rounds and proposed at 4430.

The Figure 8 shows that the proposed algorithm evenly balances the energy consumption and wise decrease of residual energy is seen. Same state is with PEGASIS with slight more steepness. LEACH energy management is really bad and DADCNS goes on exponentially decreasing.

The Figure 9 shows that the proposed algorithm and PEGASIS performs consistently while DADCNS and LEACH falls down gradually. Same is the case with the packets sent to base station in Figure 10, proposed succeeds to sent maximum data to the BS giving accurate data while rest other algorithm falls down.

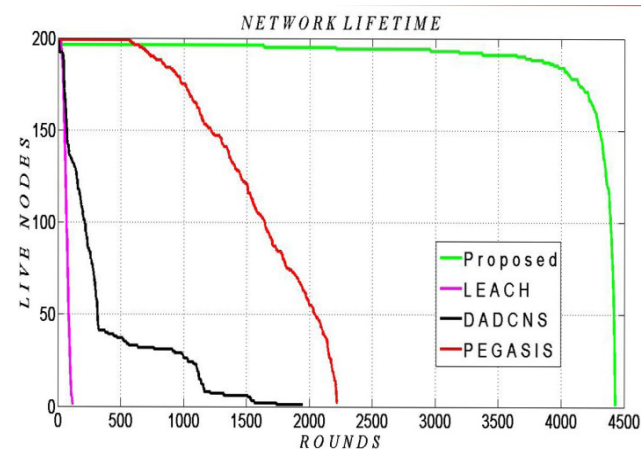


Figure 7. Network lifetime for 200nodes and 600 x 600m².

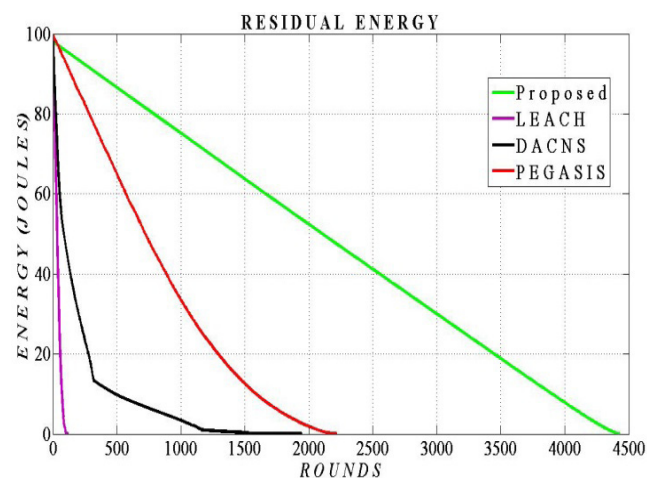


Figure 8. Residual energy of nodes area 600 x 600m².

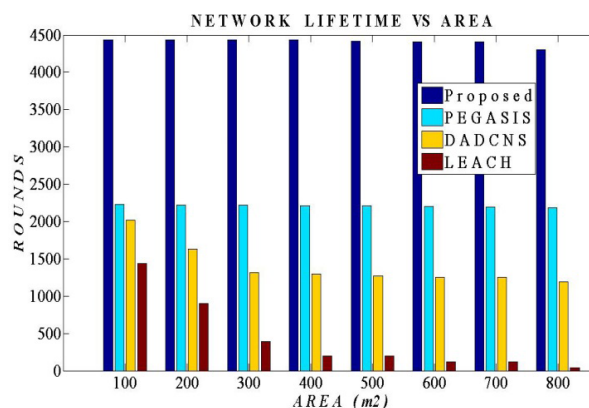


Figure 9. Network lifetime for wide range of areas.

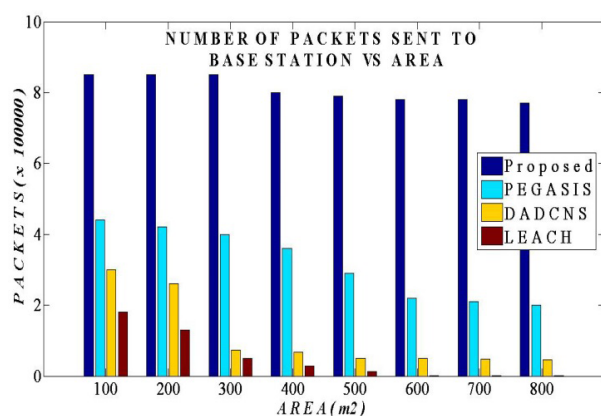


Figure 10. Number of packets sent to base station for various areas.

8. Conclusion

In this paper implementation of smart sleep mechanism and hybrid data collection technique for maximizing network lifetime in WSN's have been proposed. Here, the combination of three schemes for prolonging the network lifetime and thereby collection of large amount of data by sensors which are routed to sink is accomplished. Comparatively maximum number of nodes is alive for almost 90% of network lifetime even when the area of the field is increased. It has shown stable results even after increasing the sensing area of the network where the LEACH, PEGASIS and DADCNS degrade.

9. References

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