Dynamic Hierarchical Communication Paradigm for Improved Lifespan in Wireless Sensor Networks

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Abstract
Effective utilization of limited power resources by the sensors is pre-eminent to the Wireless Sensor Networks. Organizing the network into balanced clusters based on assigning equal number of sensors to each cluster may have the consequence of unbalanced load on the cluster heads. By-product of this is unbalanced consumption of the energy by the nodes which leads to minimization of network lifetime. We put forth a Sink administered Load balanced Dynamic Hierarchical Protocol (SLDHP) to balance the load on the principal nodes. Hierarchical layout of the sensors endows the network with increased lifespan. Outcome of this protocol also includes substantial saving of the energy consumed by the nodes. Simulation results indicate significant improvement of performance over Base station Controlled Dynamic Clustering Protocol (BCDCP).
Wireless Sensor Network, Sink, Principal Node, Superior Node, Network Lifetime.

1. Introduction

Wireless Sensor Network (WSN) is an ad-hoc wireless telecommunications network which embodies number of tiny, low-powered sensor nodes densely deployed either inside a phenomenon or close to it [1]. The multi-functioning sensor nodes operate in an unattended environment with limited sensing and computational capabilities. The advent of wireless sensor networks has marked a remarkable change in the field of information sensing and detection. It is a conjunction of sensor, distributed information processing, embedded and communication techniques. WSNs may in the near future be equally prominent by providing information of the physical phenomena of interest and ultimately being able to detect and control them or enable us to construct more meticulous models of the physical world.

WSNs are easier, faster and cheaper to deploy than other forms of wireless networks as there are no predetermined positions for the sensors. They have higher degree of fault-tolerance than other wireless networks and are self-configuring or self-organizing [2]. Sensors are deployed randomly and are expected to perform their mission properly and efficiently. Another unique feature of sensor networks is the co-operative effort of sensor nodes. These unique features have popularized the WSN in the world of communications.

A WSN is envisioned to consist of a large number of sensors and many Base Stations (BS). The sensors are supplied with transceivers to gather information from their environment and pass it on to one of the base stations. A typical sensor node consists of four major components: a data processor unit; a sensor; a radio communication subsystem that consists of transmitter/receiver electronics, antennas, an amplifier; and a power supply unit [3]. The sensors are compact in size which make them extremely energy constrained. Replacing batteries in such a large scale in harsh terrains is practically not feasible. Hence, it is well accepted that the key challenge in unlocking the potential of such networks is maximizing their post-deployment *active* lifetime. The lifetime of the sensors can be prolonged by ensuring that all aspects of the system are energy-efficient. Since communication in wireless sensor networks consume significant energy, nodes must spend as minimum amount of energy as possible for receiving and transmitting the data.

A web of sensor nodes can be deployed to gather productive information from the sensor field. The benefits of using WSNs include extended range of sensing, fault-tolerance, improved accuracy and lower cost. The sensor networks are expected to find extensive use in a variety of applications, including remote climate monitoring, seismic, acoustic, medical and intelligence data-gathering [4,5]. As a result, they are suitable for a wide range of applications like military, health, education, commerce and so on. Military applications may range from tracking enemy movements in the battlefield to guiding targetting systems. Bio-sensors are used for monitoring patients blood sugar level. Commercial applications may range from tracking postal packages to monitoring product quality on an assembly line. Environmental applications include forest-fire detection, flood detection, tracking movements of birds etc. Sensors are also used to simulate home automation and build smart environments.

Efficient utilization of energy is crucial to the WSN. Wireless microsensor network protocols should therefore be self-configuring, to enable ease of deployment of the nodes, latency aware, qualitative, robust and to extend the system lifetime. The sensors being extremely energy bounded, the communication devices on these sensors are small and have limited power and sensing range. A routing protocol coordinates the activities of individual nodes in the network to achieve the goals and does it in an efficient manner. The simplest is the Direct Communication Routing Protocol, where each node transmits the sensed information directly to the base station. The nodes consume considerable amounts of energy, if the communication path is long resulting in early death of the distant nodes. To overcome this drawback, Minimum Transmission Energy Protocol uses a multihop routing scheme. Here, nodes close to the BS drain their energy rapidly as they are involved in the transmission of messages on behalf of others. Hierarchical routing groups all the sensors into clusters. It aims at reduction of energy consumption by localizing data communications within a cluster and aggregating data to decrease the transmissions to base station.

In Low Energy Adaptive Cluster Hierarchy (LEACH), the operation is framed in iterations, with each iteration consisting of a setup phase and a data transmission phase. During the setup phase, nodes organize themselves into clusters with a predetermined number of nodes serving as cluster heads. In the data transmission phase, the self-elected cluster heads aggregate data received from nodes in their cluster, before forwarding to the base station. The role of cluster heads is randomly rotated among all the nodes in the network. LEACH serves as a basic model for other hierarchical routing protocols. A centralized version of the adaptive approach comprises of a hierarchical structure in which the base station has control over the cluster formation. The base station uses the location and energy information sent by the nodes to select the predetermined number of cluster heads. Efficient clustering is achieved as the base station possess the global knowledge of the network and hence shows improvement over the adaptive approach.

In Power Efficient Gathering in Sensor Information Systems (PEGASIS), the nodes function co-operatively to optimize network lifetime. A greedy algorithm configures the network into chains. In each iteration, a randomly chosen leader node, directs the aggregated data to the base station. A centralized energy efficient routing protocol called Base Station Controlled Dynamic Clustering Protocol (BCDCP), was proposed which widened the area for research in hierarchical routing. Here, many of the functionalities like formation of clusters and routing paths are performed by the high energy base station which in turn lightens the load of sensor nodes. This protocol configures the network into balanced clusters where each cluster head serves an approximately equal number of member nodes. Cluster head-to-cluster head multihop routing is employed in this protocol to transfer the data to the base station. The topologies of hierarchical routing protocols is depicted in Figure 1.

Efficient energy management deserves much of the attention in the WSNs. Routing protocols designed for WSNs must effectively tackle this issue in order to enhance the lifetime of the network. Hierarchical routing techniques are preferable in this direction. The arrangement of nodes in the form of a load balanced hierarchy proves to be beneficial. In the present study, an energy-efficient hierarchical routing protocol, Sink Administered Load Balanced Dynamic Hierarchical Protocol (SLDHP) is proposed to increase the lifetime of WSNs. SLDHP achieves a load balanced hierarchical arrangement of nodes in the network, and which performs significantly better than other hierarchical routing protocols.

In this work, an energy-efficient hierarchical routing protocol, SLDHP is proposed to increase the lifetime of homogeneous and heterogeneous WSNs. SLDHP achieves a load balanced hierarchical arrangement of nodes in the network which performs better than other hierarchical routing protocols.

2. Literature Survey

Heinzelman et al. [6] have proposed an adaptive clustering protocol, LEACH which employs the technique of randomly changing the role of the cluster head among all the nodes. A centralized scheme is described in [7], where the base station determines the cluster heads. The results show improvement over [6]. A chain based protocol, PEGASIS is presented in [8], where each node communicates only with a close neighbour and takes turns to transmit to the base station. A greedy algorithm ensures that the nodes already on the chain are not revisited. A centralized clustering based routing protocol, BCDCP is discussed in [9]. This protocol configures the network into balanced clusters, i.e., the number of nodes in each cluster are same. Such equal clustering results in unequal load on the cluster head.

Huang et al. [10] have reviewed the energy efficiency of cluster based routing protocols, with extended complexity of data fusion and data compression. Geographic and energy aware routing algorithm developed by Yu et al. [11] propagates a query to the appropriate geographical region without using flooding. The protocol uses energy aware and geographically informed neighbour selection to route a packet towards the target region. The protocol exhibits noticeably longer network lifetime than non-energy aware geographic routing algorithms. A novel algorithm proposed by Depedri in [12] performs the three main functions of configuring the network into optimum number of clusters, decentralised cluster head selection and cluster formation. An adaptive strategy is used for cluster head selection and the cluster formation uses total path energy dissipation instead of energy lost in the path for the node to reach its cluster head.

A cost based comparision of homogeneous and heterogeneous clustered sensor networks is presented in [13]. Here the authors propose and analyze a multihop variant of the adaptive approach where communication radius for in-cluster communication and size of clusters are taken into consideration. An energy-efficient, distributed clustering approach for adhoc sensor networks is developed in paper [14]. Here the cluster heads are chosen randomly based on their residual energy and nodes participate in cluster operation such that communication cost is minimized. In [16], a cluster-based query protocol for wireless sensor networks functions using self-organized sensor clusters to register queries, process queries and disseminate data within the network is proposed. This protocol uses cluster heads as data storage and aggregation points. Energy efficiency is achieved by reducing the number of data transmissions over the network during the course of the data collection and query processing.

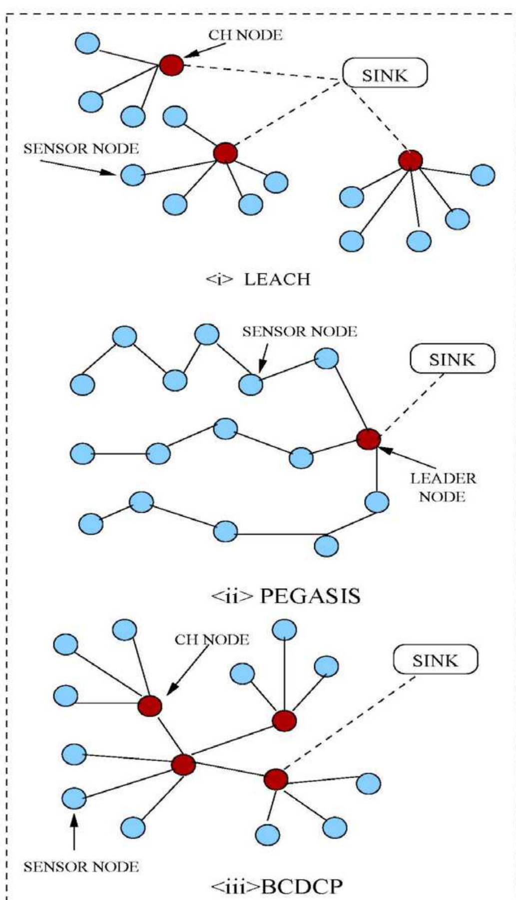

Fig. 1. Main Topologies of Hierarchical Routing Protocols

The stable election protocol described in [17] is a heterogeneous-energy-aware protocol. The weighted election probabilities, based on remaining energy of each node, is used to determine the formation of cluster head. The protocol does not consider the optimal assignment of nodes to the cluster heads. In [18], a balanced k-clustering algorithm for clustering sensor nodes into k clusters is proposed. Each cluster is balanced and the total distance between sensor nodes and the head nodes is minimized. The number of nodes is assumed to be a multiple of k at all times, which may not be feasible. A cluster based routing algorithm of [19] aims to extend the lifetime of the sensor network by maintaining uniform consumption of energy by the nodes. This protocol performs better than the adaptive approach. In [2], the authors focus on the design criteria for routing protocols and issues and challenges of cluster-based routing in WSNs.. Yunfeng et al. [20] have devised a protocol, the basic idea of which is that instead of source-initiated or destination-initiated route discovery, it is the base station that finds multipath to the source of the data and selects one of them. The problem of energy-aware routing in networks with renewable energy sources is adressed by Lin et al. [21]. The proposed static routing scheme utilizes the knowledge of traffic patterns and energy consumption, and does not demand the instantaneous information about the node energy.

3. Model

3.1 The Nomenclature

The terminology used in our study are:

Homogeneous Network Homogeneous network consists of sensors possessing uniform initial energy.

Heterogeneous Network The network in which the initial energy of the sensors is different.

$\mathbb{N}$ Set of all the sensor nodes deployed in the sensor field of the network. E_{avg} This is defined as the average energy of the wireless sensor network.

$$E_{avg} = \frac{1}{n}\sum_{k=1}^{n} E_k \quad (1)$$

where n is the number of the sensors and E_k is the energy of the k^{th} sensor. $\mathbb{P}$ Set consisting of sensor nodes with energy equal to or greater than E_{avg}, and is a subset of set $\mathbb{N}$, which is a set of all the sensor nodes deployed in the network.

Principal Node This receives the sensed data from other nodes in its hierarchy, aggregates it to forward either to another principal node or to the *Superior Node.*

Superior Node Functions as the root of the hierarchy and sends the aggregated message to the sink.

3.2 Radio Power Model

A typical sensor node is depicted in Figure 2 and consists of four major components: a data processor unit; a micro-sensor; a radio communication subsystem that consists of transmitter/receiver electronics, antennas and an amplifier; and a power supply unit. Although energy is dissipated in all of the first three components of a sensor node, energy

dissipations associated with the radio component is considered since the core objective of this study is to develop an energy-efficient network layer protocol to improve the network lifetime. In addition to this, the energy dissipated during data aggregation is the cluster heads is also accounted.
The radio energy model [9] employed in our study is described in terms of the energy dissipated in transmitting k-bits of data between two nodes separated by a distance r meters and so also the energy spent for receiving at the destination sensor node and is given by,

$$E_T(k,r) = E_{Tx} * k + Eamp(r) * k \tag{2}$$
$$E_{amp}(r) = \varepsilon_{FS} * r^2 \tag{3}$$

The energy cost incurred in the receiver is given by,

$$E_{amp}(r) = \varepsilon_{FS} * r^2 \tag{4}$$

where E_{amp} denote energy dissipated in the transmitter of the source node is required to maintain an acceptable signal-to-noise ratio for reliable transfer of data messages. We use free space propagation model and hence the energy dissipation of the amplifier is given by:

$$E_{amp}(r) = \varepsilon_{FS} * r^2 \tag{5}$$

where ε_{FS} denotes the transmit amplifier parameter corresponding to free space.
The assumed values for the various parameters is as given below.

$$E_{Tx} = E_{Rx} = 50nJ/bit$$
$$\varepsilon_{FS} = 10pJ/bit/m^2$$

The energy spent for data aggregation is $E_{DA} = 5\text{nJ/bit/message}$.

4. Problem Definition

A sensor network is described by means of an edge-weighted graph, G_{WSN}(ℕ, D, Sink), where $\mathbb{N} = \{n_1, n_2....n_n\}$ is a set of sensor nodes and $D = \{d_1, d_2....d_n\}$ is a set containing the inter-node distances existing between any two nodes.

4.1 Objectives

The objectives of our work are:
1. To design and develop an energy-efficient hierarchical routing algorithm which minimizes energy consumption of the wireless sensor network.
2. Maximizing the network lifetime.

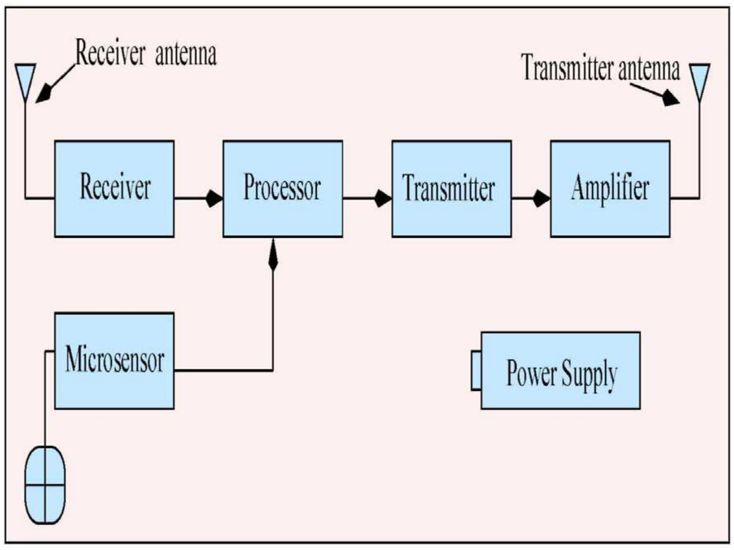

Fig. 2. A Typical Sensor Node

4.2 Assumptions

- A WSN consisting of a fixed sink with unlimited supply of energy and n wireless sensor nodes having limited power resources.
- The wireless sensor network can be either homogeneous or heterogeneous in nature.
- The sensor nodes are equipped with Global Positioning Systems (GPS).
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the sink.

5. Sink Administered Load Balanced Dynamic Hierarchical Protocol (SLDHP)

This section focuses on the design details of our proposed protocol SLDHP, which is a hierarchical wireless sensor network routing protocol. Here the sink with unrestrained energy plays a vital role by performing energy intensive tasks thereby bringing out the energy efficiency of the sensors and rendering the network endurable. The pattern of the hierarchy varies dynamically as it is based on energy levels of the sensors in each iteration. SLDHP functions in two phases namely:

1. Network Configuring Phase
2. Communication Phase.

The algorithm steps are described in Table 1.

5.1 Network Configuring Phase

The goal of this phase is to establish optimal routing paths for all the sensors in the network. The key factors considered are balancing the load on the principal nodes and minimization of energy consumption for data communication. In this phase, the sink probes and beckons the sensors to send the status message that encapsulates information regarding their geographical position and current energy level. The sink upon receiving this, stores the information in its data structures to facilitate further computations. To construct the routing path, first the sink traces the node with minimum energy, n_{min} from the set $\mathbb{N}$. The minimum energy node n_{min} will be alloted to the principal node, which will be selected based on the following criteria:

- The sink reckons the set $\mathbb{P}$, that contains nodes with energy above E_{avg}, which is a subset of set $\mathbb{N}$.
- It then computes the *Euclidean Distance* between n_{min} and each of the nodes in $\mathbb{P}$. This distance between two nodes $u = (x_1, y_1)$ and $y = (x_2, y_2)$, is described by the equation,

$$dist(u - v) = \|u - v\| \tag{6}$$

This is in turn expanded as follows:

$$\sqrt{(|x_1 - x_2|)^2 + (|y_1 - y_2|)^2} \tag{7}$$

- The node in the set $\mathbb{P}$ which has minimum distance to n_{min} is selected as the principal node.

To aid further computations, the amount of energy spent by the principal node on receiving and aggregating message sent from n_{min} is virtually reduced. The minimum energy node is then removed from the set $\mathbb{N}$. This phase repeats until all the nodes in the network are assigned to principal nodes. The last node that remains in set $\mathbb{N}$ is the node with maximum energy, designated as the superior node and has the job of sending the aggregated message to the sink.

The protocol gives prime importance to achieve balancing of load on the principal nodes. The minimum energy nodes will be assigned to a principal node as long as this node has the capability to handle them. Once the energy of the principal node falls below E_{avg}, it will be treated as a normal node and hence will be assigned to another principal node. In this way, multihop minimal spanning tree is constructed without a need for running a separate minimal spanning tree algorithm. Figure 3 depicts the hierarchical setup of the proposed protocol.

SLDHP eliminates the necessity of knowing the optimum number of clusters in the network. The load is evenly balanced depending upon the capacity of the principal nodes. The protocol starts with a chaining setup and ends in a hierarchical model. In this way, multihop, load balanced network is achieved. The concluding task of this phase is to determine the TDMA slots for all the nodes within the hierarchy. Once all the computations are over, the sink sends messages to all the sensors indicating their principal nodes and the TDMA slots.

5.2 Communication Phase

The sensors send their sensed data to their respective principal nodes. Each principal node gathers data from the nodes down in its hierarchy, fuses it and forwards either to another principal node or to the sink. This phase inturn comprises of three activities.

Data gathering utilizes a time-division multiple access scheduling scheme to minimize collisions between sensor nodes trying to transmit data to the principal node.

Data fusion or aggregation Once data from all sensor nodes have been received, the principal node combines them into a target entity to greatly reduce the amount of redundant data sent to the sink.

Data routing Transfers the data along the principal node-to-principal node routing to the superior node, which transmits the fused data to the sink.

I ***Network Configuring Phase***

(i) Initialize

- **The $Sink$ queries all the nodes regarding their status.**
- **Nodes reply by sending the status message.**

(ii) Main Processing

- **Sink computes the average energy of the network.**
- **begin**
  - **In addition to computing the average energy, the sink also does the following operations.**
    - **It traces n_{min}, which is the node with minimum energy. It then computes the set $\mathbb{P}$ which contains the node-ids of all the nodes with energy above or equal to E_{avg}.**
    - **Finds distance between n_{min} and elements of $\mathbb{P}$.**
    - **An element of $\mathbb{P}$, p_i having minimum distance to n_{min} is assigned as the principal node.**
    - **Checks whether p_i is still eligible to be in set $\mathbb{P}$. If not, it is eliminated from the set.**
    - **n_{min} is discarded from $\mathbb{N}$.**
  - **Repeat this until all the nodes have been assigned to principal nodes.**
  - **Schedules $TDMA$ slots for all the nodes.**

(iii) Finalize

- **Sink sends messages to all the nodes indicating their principal nodes and the $TDMA$ slots.**

II ***Communication Phase***

- **Data Gathering**
- **Data fusion or aggregation**
- **Data routing**

Table 1. SLDHP Algorithm

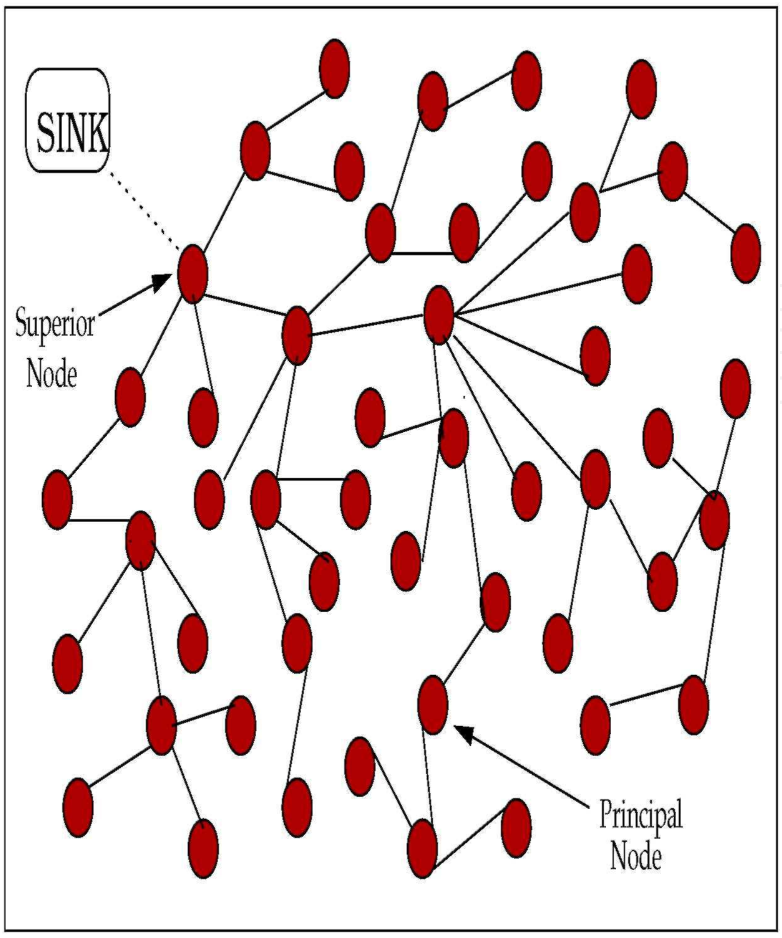

Fig. 3. Hierarchical Setup of SLDHP

6. Simulation and Numerical Results

6.1 The Test-Bed

A homogenous sensor network was set up with the simulation environment comprising 100 nodes, with all nodes possesing the same initial energy of 2J. The simulations were carried out using the OMNeT++ simulator. The sensor nodes were deployed randomly in a sensor field of a grid size of 500mx500m. The simulations were carried out several times, for different network configurations in order to obtain consistent results. The performance metrics considered are Average Energy Consumption by the nodes and Network Lifetime. The proposed protocol is compared with BCDCP.

6.2 Average Energy Consumption of the Sensor Network

Figure 4 shows the Average Energy Consumption of the sensor network, as a variation with reference to number of iterations of the network. The simulation environment is setup with the initial battery energy of all nodes being 2J and a message length of 4 kbits/packet. We observe that the protocol greatly reduces the energy consumed and hence outperforms others in terms of battery efficiency. This is due to the minimum-spanning tree hierarchical structure formed by SLDHP as compared to the cluster-based structure which consists of equal number of member nodes with unequal distribution of energy. BCDCP achieves balancing by assigning equal number of nodes to each of the clusters which results in overloading the already overloaded cluster-heads to drain out much of their energy on receiving, aggregating and transmitting the data at a much faster rate. In comparison, the proposed algorithm comprises of unequal member nodes within the hierarchy, but load balanced in terms of energy resources, which contributes significantly to the increased energy efficiency of the algorithm. Hence the packet transmission time in our algorithm is predominantly short as compared to others. From the plot, it is observed that initially when the number of iterations is less, energy consumption in both the schemes is found to be almost the same, with no conspicuous results. This is due to the fact that the hierarchical structure at this point of time seems almost the same. The real advantage comes to light when the number of iterations increases, with the hierarchical structure adapting itself dynamically to the changing scenario. The superior performance offered by SLDHP enables to achieve a reduction of energy consumption by about 21% as compared to the earlier algorithms.

6.3 Sensor Network Lifespan

The energy consumption rate can directly influence the lifespan of the sensor nodes as the depletion of battery resources will eventually cause failure of the nodes. Hence the wireless engineer is always entrusted with the task of prolonging the lifespan of the network by improving the longevity of the sensor nodes.

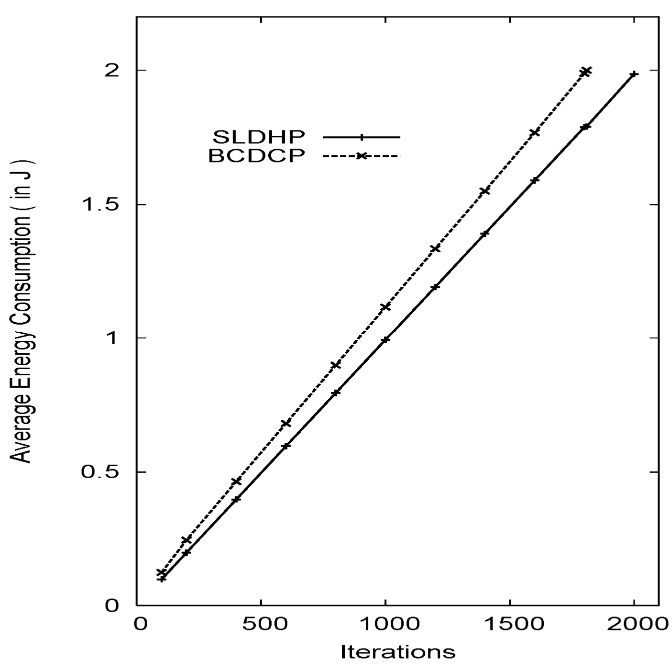

Fig. 4. Comparison of Average Energy Consumption

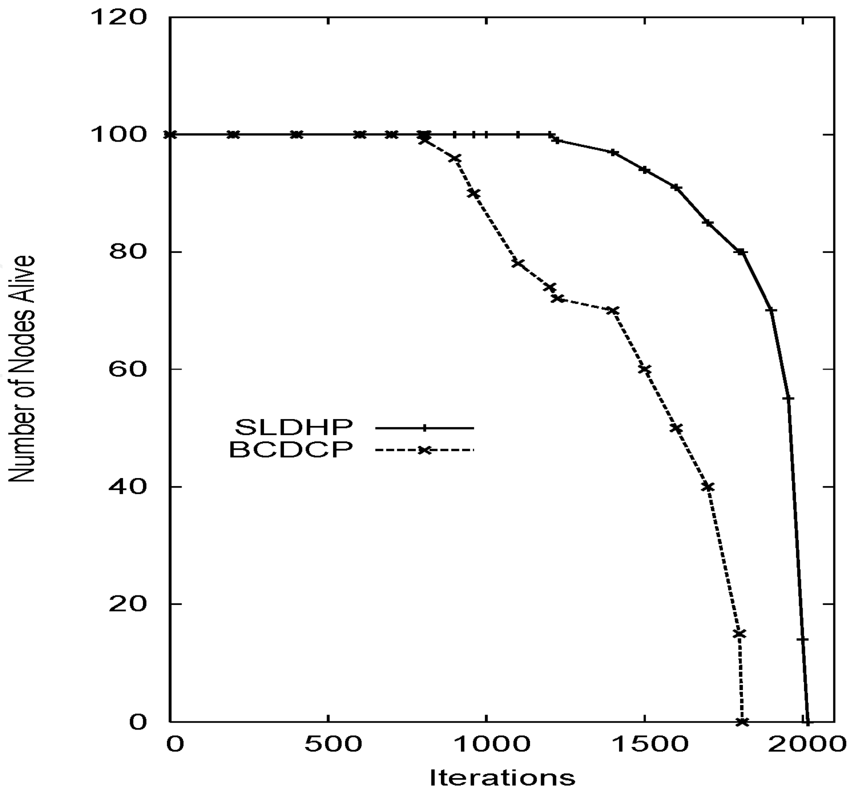

Fig. 5. Comparison of Lifespan

The simulation results of number of nodes alive over a period of time are presented in Figure 5. The simulation environment is the same, i.e., initial energy of nodes being 2J, message length being 4 kbits/packet and the initial node density being 100. Both the protocols are based on a hierarchical structure in which all the nodes rotate to take responsibility for being the cluster-head and hence no particular sensor is unfairly exploited in battery consumption. Due to the hierarchical structure, it is found that till the 806^{th} iteration, the number of nodes that are alive is almost the same in both schemes and equals 100. This implies that the time duration between the first exhausted node and the last one is quite short or the difference in energy levels from node to node does not vary greatly for lower number of iterations. After this critical point, both the curves in the Figure drop indicating the fall in the number of alive nodes. It is evident from the plot that the number of alive nodes is significantly more in our protocol as compared to other and which agrees with the results obtained in the previous simulation. This algorihm can extend the lifespan of the network by about 34% as compared to the earlier algorithm. It is observed that the number of alive nodes in earlier algorithm is a maximum of 100, dropping at a steady rate till none of the nodes are found to be alive at the 1800^{th} iteration. In comparison, the nodes of SLDHP are very much live and active even for a little beyond the 2000^{th} iteration, once again indicating the superior performance of the algorithm. The reason for this is again the same, the difference in hierarchical structure, plus the added advantage of dynamically having a load balancing scheme.

6.4 Average Energy Consumption for varying message lengths

Figure 6 shows the average energy consumption of the network when SLDHP is run with the data communication phase transmitting data at varying message lengths of 4kbits/packet and 8kbits/packet respectively. From the plot, it is observed that when the message length is 4 kbits/packet, the behaviour is exactly similar to the one depicted in Figure 4 for SLDHP due to the similarities of the simulation environment set up. When the message length is doubled, the average energy consumption of the sensor network is much more as observed from the simulation results. This is quite obvious because of greater overhead involved in aggregating and transmitting a larger sized message. From the plot, it is seen that at the end of the 2000th iteration, the energy consumed for transmitting a smaller message is close to 2J while the same energy level is reached in the 1620th iteration itself, for a larger message transmission. A message length of 4 kbits/packet seems ideal as lesser length message may not be in a position to carry out the desired task and a larger length may unnecessarily contribute to additional overhead which can degrade the performance of the network.

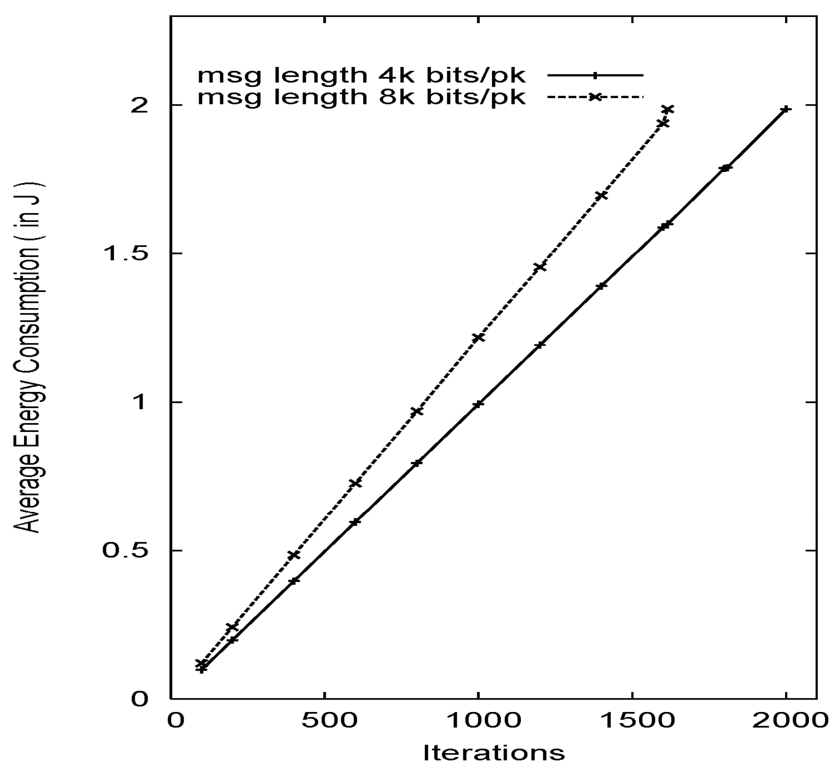

Fig. 6. Average Energy Consumption (SLDHP) with variable packet size

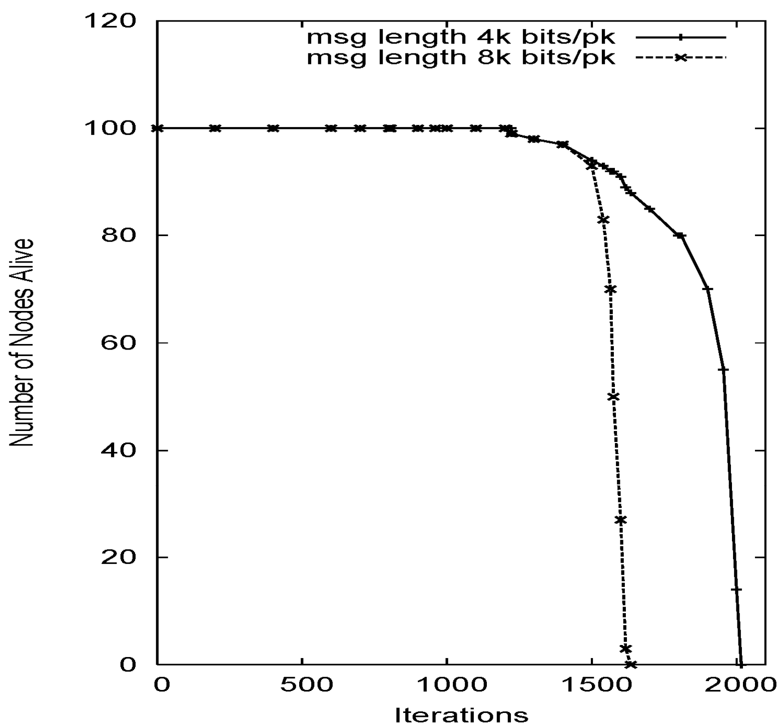

Fig. 7. Lifespan of the Wireless Sensor Network (SLDHP) with variable packet size

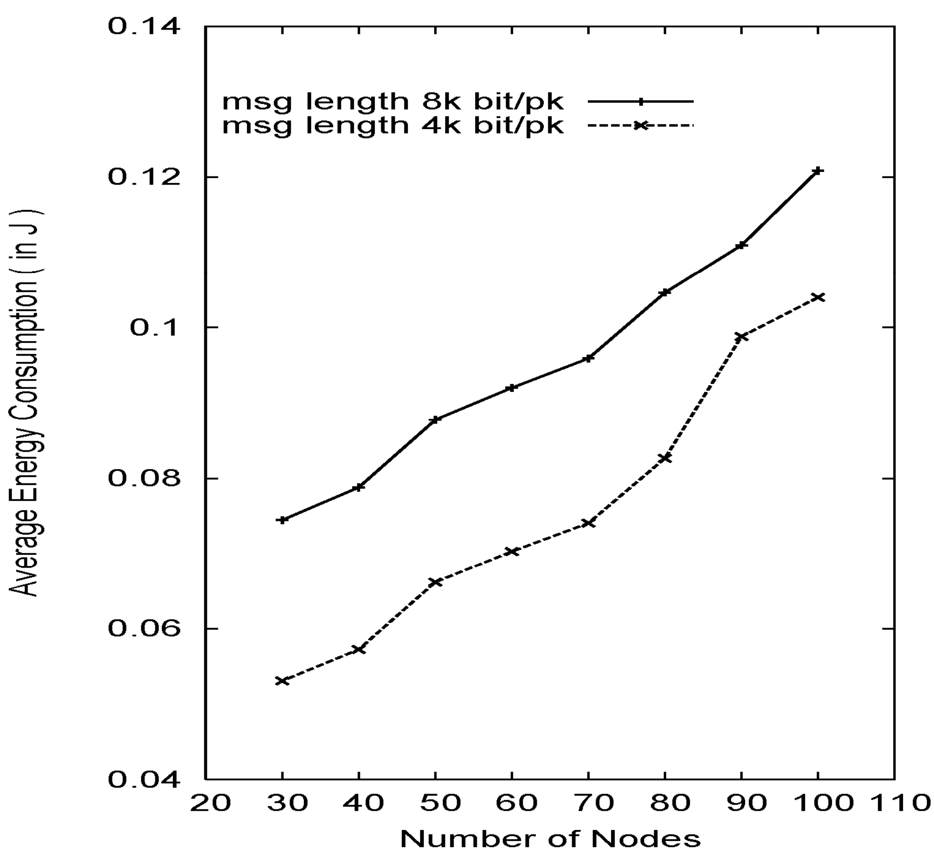

Fig. 8. Average Energy Consumption (SLDHP) for varying node density

6.5 Network Lifespan for varying message lengths

Figure 7 shows another performance run when communications in SLDHP, take place by transmitting varying length messages of 4 kbits/packet and 8 kbits/packet The simulations are carried out under similar conditions. As seen from the plot, when the message length is 4 kbits/packet, larger number of nodes are alive and the same is confirmed by the results obtained in Figure 5. When the message length is doubled, saturation of the network takes place at a faster rate due to increased overhead on the sensor nodes and the principal nodes in particular. This manifests in nodes consuming larger energy, resulting in a larger transmission cost, leading to a shorter lifespan of the network. The smaller the message length, greater is the lifespan of the network with the number of live nodes prolonging the network lifespan to as long as the 2000th iteration. Till the 1400th iteration, the number of alive nodes in both cases seems exactly the same, but drops abruptly to zero at the 1635th iteration, for a larger message length. The reason for this is the same as described for Figure 4 and hence the same inference can be drawn here as well.

6.6 Average Energy Consumption with varying node density

The plots in Figure 8 show the average energy consumption of the network with proposed algorithm run for two different message lengths. The simulation environment is set up with all the nodes equipped with a uniform initial energy of 2J. The node density is varied to account for scalability of the WSN and at the same time will aid in understanding the behaviour of the network especially in terms of energy management of the network for varying node densities. For comparatively lower value of node density, the average energy consumption of the network is smaller being a little less than 0.06 J for a smaller message length, increasing steadily to about 0.09 J for a node density of 100. In comparison, it is found that the energy consumption is relatively more for a larger sized message, varying from 0.078 J for 40 nodes reaching a value of 0.12 J for 100 nodes. This behavior is much the same as for a smaller message, the difference being that obviously more energy is consumed for a larger message size. As the number of nodes increase, the complexity of the network configuring phase also increases proportionately leading to an increased overhead on the sink to dynamically form load balanced hierarchical structures. The complexity of the data communication phase is no less, with more number of nodes being involved in data communications and with the complexity increasing with increasing nodes. The energy consumption of the network increases in proportion to the number of nodes and the same analogy holds good for different message lengths, the consumption being much more for larger sized messages.

7. Conclusions

A WSN is composed of tens to thousands of sensor nodes which communicate through a wireless channel for information sharing and processing. The sensors can be deployed on a large scale for environmental monitoring and habitat study, for military surveillance, in emergent environments for search and rescue, in buildings for infrastructure, health monitoring, in homes to realize a smart environment etc.. SLDHP manages to balance the load on the principal nodes and hence the sensor nodes are relieved from the energy intensive tasks such as formation of hierarchy and scheduling of slots to send their sensed data. This job is effectively accomplished by the high powered sink. The simulation results indicate that the network lifetime is elevated to a large extent when compared to other hierarchical routing protocols. The future work includes applying our protocol to a distributed wireless sensor network and hence to improve the network performance as in present scenario.

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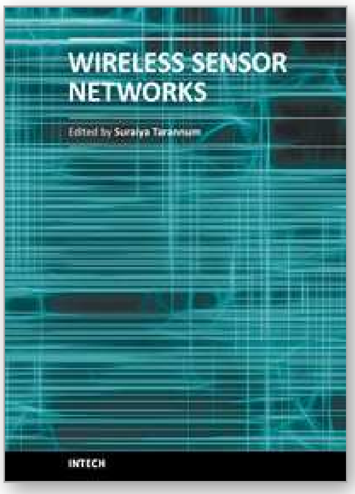

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