Location Based Clustering in Wireless Sensor Networks

Ashok Kumar, Narottam Chand and Vinod Kumar

***Abstract*—**Due to the limited energy resources, energy efficient operation of sensor node is a key issue in wireless sensor networks. Clustering is an effective method to prolong the lifetime of energy constrained wireless sensor network. However, clustering in wireless sensor network faces several challenges such as selection of an optimal group of sensor nodes as cluster, optimum selection of cluster head, energy balanced optimal strategy for rotating the role of cluster head in a cluster, maintaining intra and inter cluster connectivity and optimal data routing in the network. In this paper, we propose a protocol supporting an energy efficient clustering, cluster head selection/rotation and data routing method to prolong the lifetime of sensor network. Simulation results demonstrate that the proposed protocol prolongs network lifetime due to the use of efficient clustering, cluster head selection/rotation and data routing.

***Keywords*—**Wireless sensor networks, clustering, energy efficient, localization.

I. Introduction

THE wireless sensors are mostly deployed in remote and hazardous locations, where manual monitoring is very difficult or almost impossible. Due to the low cost of wireless sensors, these can be deployed in large numbers. Apart from sensing, sensor nodes are equipped with data processing and communication capabilities. The sensing circuitry measures the parameters of interest (temperature, pressure, etc.) within its sensing range and transforms them into electrical signals. These electrical signals are processed and with the help of onboard radio they are transmitted to the remotely located sink node. Due to deployment of wireless sensors in unattended harsh environment, it is not possible to charge or replace their batteries. Therefore, energy efficient operation of wireless sensors to prolong the lifetime of overall wireless sensor network is of utmost importance [1]–[5]. Most of the energy consumption in wireless sensor node is attributed to transmitting/receiving, processing, and forwarding the data to neighboring nodes. In literature, numbers of protocols have been proposed to manage and reduce the energy consumption [1]-[10].

Grouping sensor nodes into clusters has been widely used to achieve this objective. In clustered networks, one of the sensor nodes is elected as cluster head for each cluster. Sensor nodes in each cluster transmit data to their respective cluster head and the cluster head in turn forwards the data after aggregation/fusion to sink node through single/multi-hop transmission. The clustering process ensures efficient utilization of limited energy of sensor nodes and hence extends life time of the network [6]. A number of clustering protocols have been proposed for wireless sensor networks [9]-[25]. Most of these protocols aim at formation of stable clusters in wireless sensor networks; where node location is mostly fixed. Clustering protocols for wireless sensor network can be categorized as non-location based and location based routing protocols [2]-[3]. LEACH is one of the most popular distributed single-hop clustering protocol [13]. In this protocol, the clusters are formed, based on received signal strength. The role of cluster head is periodically rotated amongst the sensor nodes present in the cluster to ensure balanced energy consumption of sensor nodes. This algorithm becomes very inefficient in case of large area sensor networks due to single-hop communication of cluster heads to the sink. A number of improvements have been proposed in literature to overcome the shortcomings of LEACH [14], [15], [18], [21]. Some of them are LEACH-C [14], PEGASIS [18], TEEN [15], HEED [21], etc.

Ashok Kumar is with the National Institute Technology, Hamirpur, HP 177005 INDIA (e-mail: ashok.nitham@gmail.com).
Narottam Chand is with the National Institute Technology, Hamirpur, HP 177005 INDIA (e-mail: nar@nitham.ac.in).
Vinod Kumar is with the National Institute Technology, Hamirpur, HP 177005 INDIA(e-mail: kapoor@ nitham.ac.in).

In this paper, we propose an energy efficient protocol consisting of clustering, cluster head selection/rotation and data routing method to prolong the lifetime of sensor network. In proposed protocol, clusters are formed only once during the lifetime of sensor network, which results in substantial saving of energy. The clustering process in the proposed method is a decentralized process, which is carried out by sensor nodes autonomously, without any radio communication to the sink, thus saving the node energy. The cluster head rotation depends on the residual energy of a cluster head and rotation frequency/timing is based on energy consumption of sensor nodes for various tasks performed by them during the lifetime of sensor network. This ensures balanced energy consumption of all sensor nodes present in a cluster, resulting in prolonged network lifetime. A simple routing method is proposed; where each cluster head transmit the data to its nearest next-hop cluster head in the direction of sink.

The rest of the paper is organized as follows: Section II describes the system model, which includes network model and energy dissipation model for wireless sensor networks. Section III describes proposed protocol, including formation of clusters, cluster head selection, cluster head rotation. Results of simulations for various performance metrics are given in Section IV. Concluding remarks and direction for future work have been incorporated in Section V.

II. System Model

Wireless sensor network model based on circular monitoring area A of radius Z with uniform node distribution density ρ having only one sink node at the center of monitoring area has been considered. There are T sensor nodes deployed in the sensing area, designated as N_1, N_2, …. N_T. Such model has been widely used in literature [14]. It is assumed that the transmitter electronics of all sensor nodes is capable of transmitting the data with two types of radio ranges: low power broadcast range R_1=R/2 meters and high power range of R_2=R meters, where R is the maximum transmission range of a node. Low power broadcast range R_1 is used for intra cluster communication between a sensor node and cluster head. The maximum diameter of any cluster is assumed to be R/2 meters, so that even if a node is located at boundary of a cluster, it may be selected as cluster head, and data connectivity is still maintained between the sensor nodes and cluster head within the cluster. High power broadcast rang R_2 is used by cluster head node to transmit data either to next hop cluster head or to the sink node, in case the sink node is at a distance of one hop from the cluster head. The proposed model ensures that two neighboring cluster heads are always at maximum distance of R from each other, so that connectivity is always maintained between such nodes. Data sensing and data gathering operation of sensor network is divided into rounds. In each round, the, sensor nodes sense the desired variable of interest e.g. temperature, pressure, etc. around its periphery within the sensing area. The sensed data is converted into digital data of k bits length and transmitter electronics sends the data to its designated cluster head within the cluster.

For intra cluster communication, TDMA scheduling is assumed to avoid any collision among the data transmitted by various sensor nodes [25]. It is assumed that in each cluster TDMA schedule is managed by cluster head for its own cluster members. As the data from various sensor nodes arrive at the cluster head, it performs data aggregation or data fusion over the arrived data as per the nature of sensed data to reduce the transmission overhead.

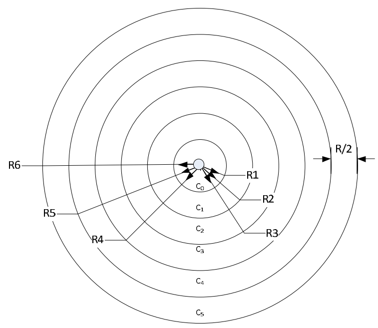


Fig. 1 Corona based wireless sensor network model.

The cluster head transmits the aggregated/fused data to its next hop cluster head towards sink node. To avoid the collision of inter cluster data; multiple access technique of direct sequence spread spectrum (DS-SS) is assumed [24]. DS-SS scheme avoids data collision of inter cluster data by assigning different codes for each cluster head within the sensing area. All sensing nodes deployed in the sensing area are assumed to be static and have the knowledge of their location. It is assumed that localization process is carried out just after the deployment of sensor nodes. A number of localization approaches are reported in the literature for wireless networks [25]-[30]. The sensing field is divided into m numbers of concentric circles of equal width, known as corona [31]. In proposed model, the width of each corona is assumed to be R/2 meters, as illustrated in the Fig 1.

Generalized energy consumption model based on first order radio energy consumption is used for calculation of energy consumption for sensor nodes within the sensing area [13], [14, [30]. The radio propagation model (path loss model) for wireless sensor node is illustrated in Fig 2.

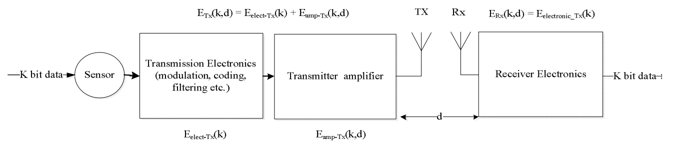


Fig 2. Energy Model Wireless Sensor Network.

The energy consumption of a sensor node for transmitting k bits of data over a distance d can be expressed as [14], [30]:

$$E_{Tx}\left(k,d\right) = E_{elect-Tx}(k) + E_{amp-Tx}(k,d) \tag{1}$$

$$E_{Tx}\left(k,d\right) = \begin{cases} kE_{elect} + k\epsilon_{fs}d^2, & d < d_0 \\ kE_{elect} + k\epsilon_{mp}d^4, & d \geq d_0 \end{cases} \tag{2}$$

$E_{elect-Tx}$ is transmission electronics energy; which is energy consumed by the sensor node for modulation, coding, spreading schemes, filtering operations, etc. E_{amp-Tx} (k,d) is the power amplifier stage energy consumption of sensor node to transmit k bits of data over a distance of d meter with acceptable signal to noise ratio (SNR). k is the number of bits transmitted over a distance d (distance between transmitter and receiver). E_{elect} (nJ/bit) is energy dissipation per bit to run transmitter and receiver electronic circuitry. ε_{fs} (pJ/(bit-m^{-2})) is energy coefficient of power amplifier stage of sensor node for free space energy dissipation model, when transmission distance is less than threshold i.e. $d < d_0$. ε_{mp} (pJ/(bit-m^{-4})) is energy coefficient of power amplifier stage of sensor node for multipath energy dissipation model, when transmission distance is greater than threshold i.e. $d \geq d_0$.

The energy consumption of sensor node to receiver k bits of data is given by:

$$E_{Rx} = kE_{elect} \tag{3}$$

III. Proposed Protocol

The proposed protocol has been segregated into different phases: simultaneous selection of cluster head and creation of balanced size clusters to prolong the sensor network lifetime, data aggregation/fusion, routing of data to the sink node and cluster head rotation and subsequent round cluster head selection. After the deployment of sensor nodes in sensing area, the clustering and cluster head selection phase starts with transmission of beacon by sink node using omni-direction antenna. The beacon contains information regarding the location of sink node (x_s, y_s) within the network. After receiving the sink node location, all the sensor nodes calculate their respective Euclidian distance from the sink node. Let us assume that the i^{th} sensor node Ni is located at (x_i, y_i). The distance d_{si} between sensor node and sink can be calculated as:

$$|d_{si}| = \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2} \tag{4}$$

i = 1, 2, 3, ……… T; where T is total number of sensor nodes in the network.

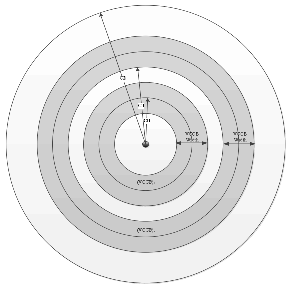
Once, all sensor nodes calculate their respective distance from the sink node, the formation of concentric circles around the sink node starts. In this process the sensor nodes are assigned concentric circle index C_j (j = 1, 2, 3, ….. m), each of width R/2. The assignment of concentric circle to the sensor node N_i is carried out with the formula:

$$C_j = \frac{2|d_{si}|}{R} \tag{5}$$

Where, d_{si} is distance of sensor node from the sink node and R is radio range of the sensor node transmitter for inter cluster communication. For example, the assignment of concentric circles to the nodes located at various locations in sensing area for R=3 meters is shown in Fig 3.

Distance of Node from the Sink	Assigned Concentric Circle (C_j)
1.5m	C_1
1.6m	C_2
3.1m	C_3
4.4m	C_3

(a)



(b)

Fig. 3 Assignment of concentric circles band (VCCB) to the sensor nodes

The proposed method of associating sensor nodes to various concentric circles is quite energy efficient as every node can associate itself to a particular concentric circle simply by calculating its distance from the sink node. In the proposed model, a node does not need to transmit its location information to the sink as done in [1], where multiple data transmission and reception operations are performed within the network. Multiple transmit-receive operations involved in the process lead to high energy consumption if the network size is large. It also leads to the additional delay in cluster formation.

A. Cluster Formation and Cluster Head Selection

To achieve energy balanced clustering in the network, concept of virtual concentric circle band (VCCB) is proposed. Virtual concentric circles are designated as V_1, V_2, V_3…, and are shown in Fig 3. A virtual concentric circle band lies at the midway between two concentric circles and has width ± δ i.e. 2δ. The index V_j of virtual concentric bands can be calculated as:

$$V_j = \left[\left\{ \left(\frac{R}{2} * C_i \right) + \frac{R}{4} \right\} \pm \delta \right] \tag{6}$$

$$\begin{aligned} &if \quad x_i = \left\{ \left(\frac{R}{2} * C\_i \right) + \frac{R}{4} \right\} \\ &then \qquad V_j = [x_i \pm \delta] \end{aligned} \tag{7}$$

The information regarding the sensor node radio range R is known apriori to all nodes and value of δ is made known to all sensor nodes at the time of node deployment. The value of δ depends on the node density in the sensing area. If the sensing area is densely populated with sensor nodes, δ value is small, on the contrary for sparsely populated sensing area, the value of δ is kept large. The reason for choosing such values of δ is due to the fact that for densely populated area, probability of finding sensor nodes near the center of concentric circle is high and for cluster formation, probable cluster head can be found near to the center. Whereas, if the sensor node density is low, opposite is the case and value of δ need to be kept high to ensure the first round cluster head selection within the VCCB. The value C_i (concentric circle index) is calculated in the first phase by all sensor nodes as explained earlier.

All sensor nodes in the network calculate their respective VCCB index V_j and compare it with their respective distance from the sink node d_{si}. If the distance d_{si}, falls within the VCCB index [x_i ± δ]; the sensor node is declared as a probable candidate for the election of cluster head (CH) in the first round. All other sensor nodes, for which the value of V_j does not fall within [x_i ± δ] , opt out from the process of cluster head selection for the first round and wait for the declaration of first round cluster head, to associate themselves with one of such declared cluster head. On completion of the process of selection of probable candidates for first round cluster head, the process of first round cluster head election starts. The best possible candidate for the election of first round cluster head would be the one located exactly midway between the two concentric circles. For the first round cluster head election, it has been assumed that the energy of all probable cluster head candidates is same. Therefore, only location of cluster head candidate has been used as sole criteria for first round cluster head selection. Mathematically, the optimal location (in terms of distance from the sink node) for first round cluster head can be calculated as:

$$d_{optimum} = \left[\left(\frac{R}{2} * C_i\right) + \frac{R}{4}\right] \quad (8)$$

$d_{optimum}$ value falls exactly at the center of virtual concentric circle band (VCCB). The concept of back-off timer is used for election of first phase cluster head. The initial value of back-off timer is based on location of the cluster head candidate in the VCCB. It is made proportional to the distance of cluster head candidate from the center of VCCB. Smaller the distance, smaller will be the initial value of back-off timer. All the probable cluster head candidates calculate their distance from center of their respective VCCB as:

$$d_{i(vc)} = \left\| \left[\left\{ \left(\frac{R}{2} * C_i\right) + \frac{R}{4} \right\} - d_{si} \right] \right\| \quad (9)$$

Initially back-off timer value of node N_i is set to be t_i, and is given by:

$$t_i = \frac{d_{i(vc)}}{\delta} * T_{ch} \quad (10)$$

Where T_{ch} is the time allocated for the first round cluster head election. The above equation can be modified to mitigate the possibility of more than one cluster head candidates declaring themselves as cluster head simultaneously within the same cluster during the selection process, if they are lying at same distance from the center of their respective VCCB. The modification is carried out by adding a random value in the interval (0, 1), to the equation. The modified equation is given by:

$$t_i = \left[\frac{d_{i(vc)}}{\delta} * T_{ch}\right] + rand(0,1) \quad (11)$$

Where, rand(0, 1) designate random value in the interval (0, 1). The value of $d_{i(vc)}$ has been normalized to make the ratio $d_{i(vc)}/\delta$ fall within (0, 1). The sink node assists the cluster head formation by sending START message, which directs all the probable cluster head candidates in the network to start their back-off timer at same time. As the back-off timer value is directly proportional to the distance of cluster head candidate from center of VCCB, the back-off timer of the node near to the center will expire first. As soon as the back-off timer of particular cluster head candidate expires, it sends advertising message CH_ADVT, declaring itself as first round cluster head. This message will be transmitted within the radio range (R/4) of sensor node. Any other probable cluster head candidate within the radio range (R/4) of the node which has declared itself as cluster head, will stop its back-off timer and associate itself with the declared cluster head for formation of cluster. Similarly all non-cluster head candidates, falling within the radio range (R/4) of declared cluster head, will also associate themselves with the cluster head and thus form a uniform cluster. Same process takes place in all the concentric circles throughout the sensing area and simultaneous cluster head selection and cluster formation takes place within the network. The process of cluster formation and cluster head selection is decentralized in proposed model as compared to centralized clustering and cluster head selection reported in [25], where the sink node carries out the clustering process within the sensing area. The centralized cluster formation process involves transmission and reception of large number of messages between sensor nodes and sink node. This leads to huge energy consumption for large wireless sensor network, reducing its life time. It also causes additional delay in cluster formation.

The role of cluster head in a cluster must be rotated regularly amongst the sensor nodes to prolong the life time of sensor network by balancing the energy consumption of various sensor nodes. Since, cluster head is required to perform extra task of data gathering and data relaying, compared to the regular sensor nodes, its energy drains out faster. Therefore, some mechanism must be adopted to rotate the role of cluster head. The rotation mechanism must ensure balanced energy consumption of all the sensor nodes in cluster. A number of methods for cluster head rotation have been discussed in the literature [13]-[19]. Most of these methods are based on residual energy of cluster head or distance of prospective cluster head from the center of the cluster. If uniform transmission power is assumed for intra cluster communication and cluster is assumed to be static, the distance parameter of elected cluster head from center of cluster becomes insignificant, since power consumption for communication remains same irrespective of the location of cluster head inside the cluster. For such cases, the residual energy of cluster head is important parameter to initiate the process of cluster head rotation. For our proposed model, the cluster head rotation process has been performed based on the residual energy of the cluster head, as explained in the next section. The frequency and timing of cluster head rotation process, aimed at optimum life time of wireless sensor network, is decided by calculating the energy consumption for regular sensor nodes and cluster head nodes for various tasks performed by these nodes including data relaying and cluster head selection/rotation. After assessing the actual energy consumption of sensor nodes, the balanced energy consumption is ensured by optimal rotation of cluster head node at regular intervals.

IV. Performance Evaluation

In this section the performance of proposed protocol is evaluated through simulation experiments. We have implemented the simulator in MATLAB. The performance of our protocol is compared with ERP-SCDS [25] protocol. The performance metrics include ratio of single node clusters, clustering energy dissipation, total energy dissipation per rounds, and life-time of network. The probability of signal collision and signal interference is ignored, assuming TDMA scheduling for intra cluster and DS-SS for inter cluster communication. The simulation parameters are listed in Table I. For each parameter, simulation has been run many times and average result of all runs has been taken for evaluation.

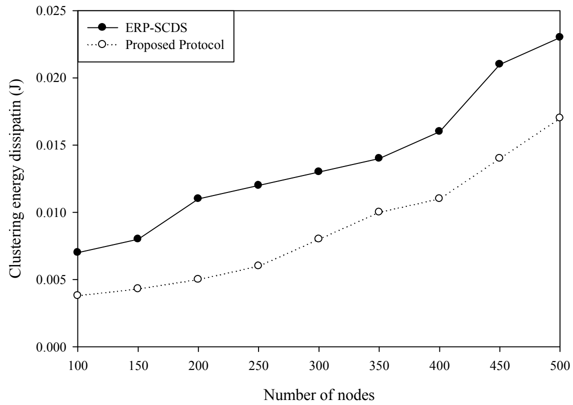
TABLE I
SIMULATION PARAMETERS

Parameter	Default Value	Range
Area	(100×100) m2	(50×50)~(400×400) m2
Number of nodes	400	100~500
Initial Energy of node	2 Joule	
Data packet size (k)	100 byte	
(E_{elect})	50 nJ/bit	
(ϵ_{fs})	10 pJ/bit/m2	
(ϵ_{mp})	0.00134 pJ/bit/m4	
(E_{aggr})	5 nJ/bit/signal	
Threshold distance (d0)	87 meters	

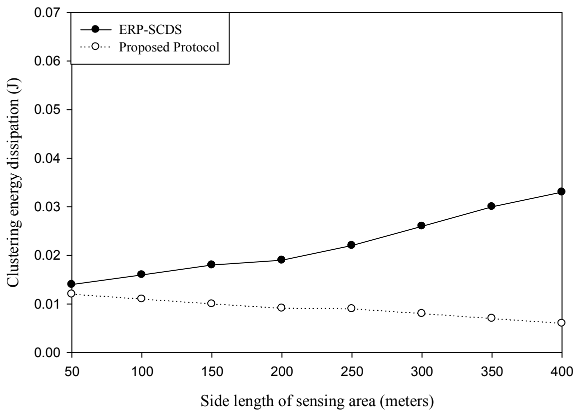
A. Simulation Results

1) Clustering Energy Dissipation

Minimum clustering energy requirement can prolong the network lifetime and can be used as parameter to demonstrate the efficiency of any clustering and routing protocol. Fig 4 shows the variation in clustering energy dissipation with variation in number of nodes and area of sensing field. Fig 4(a) shows the simulation results of variation in clustering energy dissipation, in case of ERP-SCDS and proposed protocol with variation in number of nodes from 100 to 500, when nodes are randomly deployed in a sensing field of 100×100 m2. Clustering energy requirement of ERP-SCDS is more than the proposed protocol. Since, it requires the location information transmission of every node to the sink and after receiving this information, the sink initiates the clustering process, dissipating more energy than our proposed protocol. This process involves large number of transmit/receive operations, increasing the clustering energy cost. In case of our protocol, first round cluster head selection and clustering is carried out simultaneously throughout the network. It uses less number of transmit/receive operations since, less number of control messages are exchanged for clustering. Fig 4(a) shows that the clustering energy increases with increase in the number of nodes in sensing field. This increase can be attributed to the fact that with increase in number of nodes, number of transmit/receive operations will increase, thus increasing the clustering energy dissipation. Fig 4(b) shows the simulation results of variation in the clustering energy dissipation with increase in sensing area side length from 50 to 400 meters, when 400 number of nodes are deployed. The simulation results show the increase in clustering energy dissipation ERP-SCDS. In case of ERP-SCDS, this increase in clustering energy dissipation can be attributed to more transmission of location information messages from all sensor nodes to the sink with increase in distance of nodes from the sink.



(a)

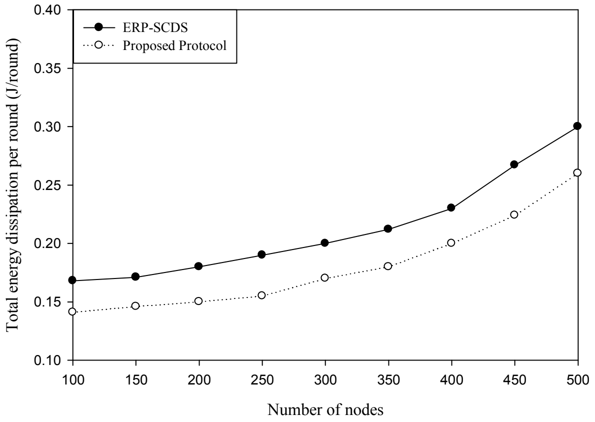


(b)

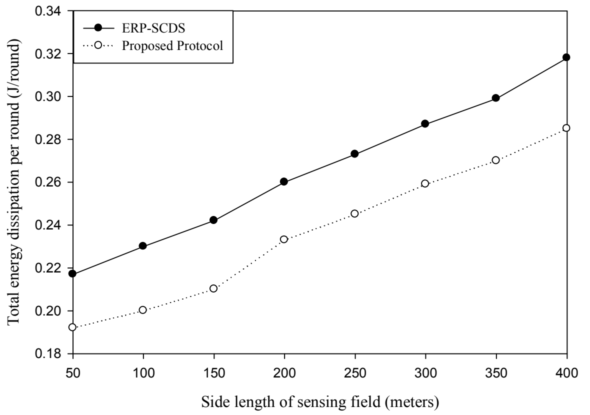
Fig. 4 Variation in clustering energy dissipation with (a) number of nodes deployed in sensing field, and (b) side length of sensing field

2) Total Energy Dissipation Per Round

Total energy dissipation per round is the energy dissipated within sensor network for sensing the desired parameters (e.g. temperature, pressure, etc.) and transmitting the sensed data to the sink. Fig 5 shows the simulation results for variation in energy dissipation per round in case of ERP-SCDS and our protocols. The variation in energy dissipation per round has been studied by varying number of nodes from 100 to 500, keeping the area of sensing field 100×100 m2. It is observed that the total energy dissipation per round increases with increase in the number of nodes, since, increased number of nodes lead to the increase in total sensing energy, total aggregation energy and routing energy. The simulation results show that our protocol outperforms the ERP-SCDS protocol, in terms of total energy dissipation per round. This is due to the presence of less number of single node clusters and less number of cluster formation in our protocol.



(a)



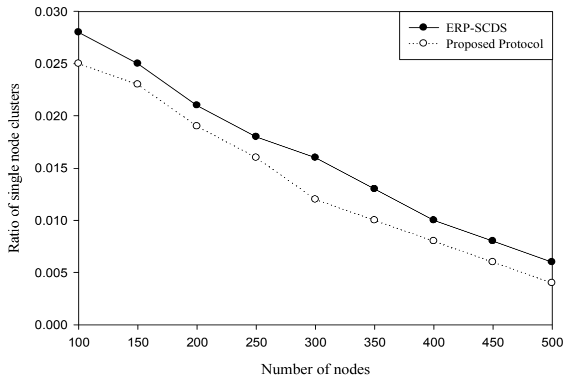
(b)

Fig. 5 Variation in total energy dissipation per round with (a) number of nodes deployed in sensing field, and (b) side length of sensing field

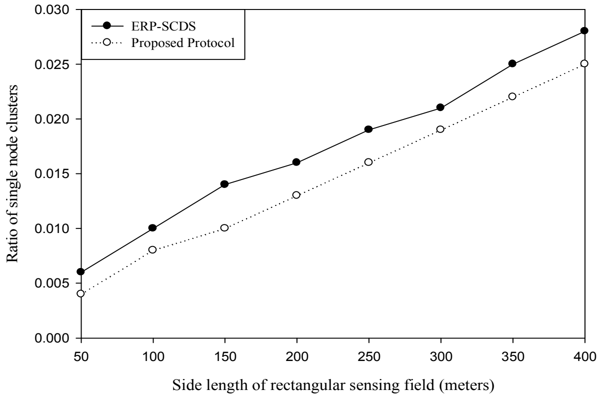
Fig 5(b) shows the simulation results for effect of variation of square sensing field side length from 50 to 200 meters, keeping the nodes deployment fixed at 400. It is observed that the sensing energy dissipation increases with increase in the area of sensing field, since, the distance between sink and sensing node increases with increase in the area of sensing field, which increases the data transmission energy cost. The performance of our protocol is better than ERP-SCDS protocol due to less increase in number of single node clusters with increase in area of sensing field.

3) Ratio of Single Node Clusters

Ratio of single node clusters is defined as the ratio of number of single node clusters to the total number of clusters.



(a)



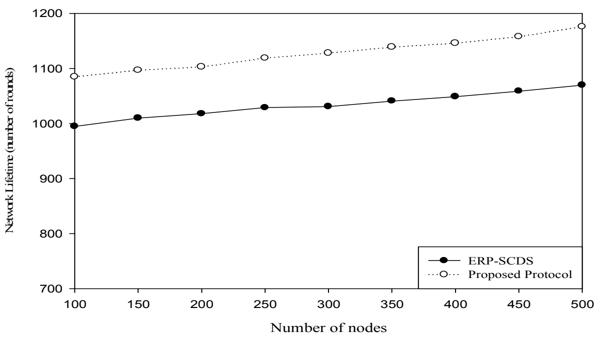
(b)

Fig. 6 Variation in ratio of single node clusters with (a) number of nodes deployed in sensing field, and (b) side length of sensing field

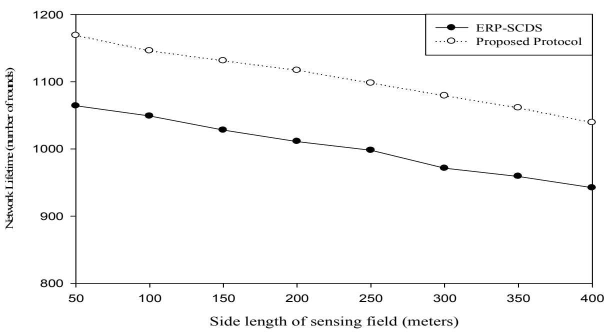
High ratio of single node clusters indicates the unbalanced cluster formation in the sensing field and leads to reduced network lifetime. Fig 6 shows the simulation results of variation in single node cluster ratio for ERP-SCDS and our protocol. The variations has been studied with increase in number of nodes from 100 to 500 in sensing field of 100×100 m^2 and with increase in side length of sensing area from 50 to 400 meters having random deployment of 400 nodes. ERP-SCDS generates clusters around virtual points fixed by the sink within sensing field. The formation of clusters around these virtual points helps the generation of more balanced clusters in case of small area sensor networks or sensor networks with large number on node deployment. Our protocol provides best performance, having lowest number of single node clusters due to balanced cluster formation. The ratio of single node clusters increases with increase in the side length of sensing field, because with increase in the sensing area, node density decreases, increasing the possibility of single node clusters.

4) Network Lifetime

Network lifetime of wireless sensor network is the time span from the deployment to the instant the network ceases to achieve objectives of its deployment. The definition of network lifetime is application specific. In strategic applications, where even small part of sensing area cannot be lefts unattended, the lifetime of network is considered as the time span from the deployment to the instant, first node in the network dies (FND).



(a)



(b)

Fig. 7 Variation in network lifetime with (a) number of nodes deployed in sensing field, and (b) side length of sensing field

For some other applications, network lifetime may be considered as the time span in which a specific percentage of nodes die, such as half node dies (HND). In some cases it could be the time span in which last node of sensor network dies. In this paper, we have considered number of rounds till first node dies (FND), as parameter for the evaluation of proposed protocol and existing protocols. Fig 7 shows simulation results of variation in network life time, i.e. total number of rounds from the deployment to the instant when first node dies in the network.

In Fig 7(a) the number of rounds has been plotted against number of sensor nodes varying from 100 to 500 deployed in sensing field of 100×100 m^2. The simulation results show that the proposed protocol exhibits better lifetime than ERP-SCDS protocol. ERP-SCDS requires more energy for clustering, causing less lifetime of network in comparison to the proposed protocol. Our protocol shows higher network lifetime than ERP-SCDS, because, it require less energy for clustering, the cluster formed are well balanced and cluster head rotation is carried out considering all kinds of energy consumption within the network, providing more balanced energy depletion of sensor nodes in the cluster. In case of both of these protocols, the network lifetime increases with increase in the number of sensor nodes. As can be seen from previous simulations that increase in number of nodes within fixed area sensing field produces more balanced clustering structures, increasing number of nodes per cluster, and decreasing percentage of single node clusters. All these parameters result in increased lifetime of network. Fig 7(b) shows the simulation results of variation in network lifetime with increase in side length of sensing field from 50 to 400, keeping the node deployment fixed to 400. Simulation results show that network lifetime decreases with increase in area of sensing field with fixed number of node deployment; due to decreased number of nodes per cluster, and increase in percentage of single node clusters. Our protocol exhibits better network life time in comparison to ERP-SCDS protocol, despite increase in network area. This is due to the fact that in case of proposed protocol, the decrease in number of nodes per cluster, and increase in percentage of single node clusters is smaller in comparison to ERP-SCDS protocol. This leads to better network lifetime in case of our protocol, despite increase in network area.

V. Conclusions

An energy efficient clustering, cluster head selection/rotation and data routing protocol is proposed in this paper. The proposed protocol ensures the formation of uniform clusters in virtual concentric circular bands around the sink. In proposed method the cluster formation takes place only once in network lifetime, thus avoiding energy wastage associated with re-clustering process. The cluster head rotation process is based on energy calculation of various tasks performed by the sensor nodes and cluster head in a cluster. The timing and frequency of cluster head rotation is carried out by balancing the energy consumption. This results in balanced energy drainage of the node in network, improving the network lifetime. The simulation results demonstrate the effectiveness of proposed protocol in term of clustering energy dissipation, total energy per round, number of clusters in the network and improved network lifetime. The simulation results are also compared with ERP-SCDS protocol. The proposed protocol provide better results in comparison to this protocol and can be used in wireless sensor networks for prolonging the network lifetime. The protocol can be extended in future to the wireless sensor network with non-uniform energy distribution and sensor network with mobile sensor nodes.

References

[1] C.Y. Chong and S.P. Kumar, “Sensor networks: Evolution, Opportunities, and Challenges,” Proceedings of the IEEE, vol. 91, no. 8, pp. 1247–1256, August 2003.
[2] Ameer Ahmed Abbasi and Mohamed Younis, “A Survey on Clustering Algorithms for Wireless Sensor Networks,” Elsevier Journal of Computer Communications, vol. 30, pp. 2826–2841, October 2007.
[3] Olutayou Boyinbode, Hanh Le, Audrey Mbogho, Makoto Takizawa, and Ravi Poliah, “A Survey on Clustering Algorithms for Wireless Sensor Networks,” International Conference on Network-Based Information Systems, Gifu, Japan, pp. 358-364, September 2010.
[4] A. Abbasi and M. Younis, “A Survey on Clustering Algorithms for Wireless Sensor Networks,” Elsevier Journal of Computer Communications, vol. 30, pp. 2826-2841, October 2007.

[5] Xiaobing Wu, Guihai Chen and S.K. Das, “Avoiding Energy Holes in Wireless Sensor Networks with Nonuniform Node Distribution,” IEEE Transactions on Parallel and Distributed Systems, vol. 19, no. 5, pp. 710-720, May 2008.

[6] M. Younis, M. Youssef and K. Arisha, “Energy-Aware Management in cluster-Based Sensor Networks,” International Journal on Computer Networks, vol.43, no. 5, pp. 649–668, December 2003.

[7] D.J Baker and A. Ephremides, “The Architectural Organization of a Mobile Radio Network via a Distributed Algorithm,” IEEE Transactions on Communications, vo. 29, no.11, pp. 1694-1701, 1981.

[8] D.J Baker and A. Ephremides, “The Design and Simulation of a Mobile Radio Network with Distributed Control,” IEEE Journal on Selected Areas in Communications, vol. 2, no.1, pp. 226-237, January 1984.

[9] A. Ephremides, J.E. Wieselthier and D.J. Baker, “A Design Concept for Reliable Mobile Radio Networks with Frequency Hopping Signaling,” Proceedings of IEEE vol. 75, no.1, pp.56-73, January 1987.

[10] K.Xu and M. Gerla, “A Heterogeneous Routing Protocol Based on A New Stable Clustering Scheme,” Proceeding of IEEE Military Communications Conference, Anaheim, CA, pp. 123-131, October 2002.

[11] R. Nagpal and D. Coore, “An Algorithm for Group Formation in an Amorphous Computers,” Proceedings of 10th International Conference on Parallel and Distributed Systems (PDCS’98), Las Vegas, NV, October 1998.

[12] M. Younis, K. Akkaya and A. Kunjithapatham, “Optimization of Task Allocation in A Cluster–Based Sensor Network”, Proceedings of the 8th IEEE Symposium on Computers and Communications (ISCC’2003), Antalya, Turkey, June 2003.

[13] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, “Energy-Efficient Communication Protocol for Wireless Micro Sensor Networks” Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), vol.2, pp. 234-243, January 2000.

[14] 14. Wendi B. Heinzelman, Anantha P. Chandrakasan and Hari Balakrishnan, “An Application-Specific Protocol Architecture for Wireless Microsensor Networks”, Transactions on Wireless Communications, Vol. 4, pp.660 –670, October 2002.

[15] A. Manjeshwar and D. Agrawal, “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” Proceedings of 15th International Parallel and Distributed Processing Symposium (IPDPS’01), San Francisco, CA, pp. 2009-2015, April 2001.

[16] A. Manjeshwar and D. Agrawal, “APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks,” Proceedings of International Parallel and Distributed Processing Symposium (IPDPS’02), Fort Lauderdale, Florida, pp.195-202, April 2002.

[17] An Amir Sepasi Zahmati, Bahman Abolhassani, Ali Asghar Beheshti Shirazi, and Ali Shojaee Bakhtiari, “Energy-Efficient Protocol with Static Clustering for Wireless Sensor Networks,” World Academy of Science, Engineering and Technology vol. 28, pp. 69-72, 2007.

[18] S. Lindsey and C. Raghavendra, “PEGASIS: Power-Efficient Gathering in Sensor Information Systems,” Proceedings of IEEE Aerospace Conference, Big Sky, Montana, USA, vol.3, pp.1125-1130, March 2002.

[19] M. Demirbas, A. Arora and V. Mittal, “FLOC: A Fast Local Clustering Service for Wireless Sensor Networks,” Proceedings of Workshop on Dependability Issues in Wireless Ad Hoc Networks and Sensor Networks (DIWANS’04), Palazzo dei Congressi, Florence, Italy, June 2004.

[20] M. Ye, C. Li, G. Chen and J. Wu, “An Energy Efficient Clustering Scheme in Wireless Sensor Networks,” Journal of Ad Hoc & Sensor Wireless Networks, Vol.1, pp. 1–21, 2006.

[21] O. Younis and S. Fahmy, “HEED: A Hybrid Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks,” IEEE Transactions on Mobile Computing, vol. 3, no.4, 2004.

[22] C. Li, M. Ye, G. Chen and J. Wu, “An Energy-Efficient Unequal Clustering Mechanism for Wireless Sensor Networks,” Proceedings of IEEE International Conference on Mobile Ad hoc and Sensor Systems Conference(MASS05), Washington, D.C., pp. 604-611, November 2005.

[23] S. Yi, J. Heo, Y. Cho, and J. Hong, “PEACH: Power-Efficient and Adaptive Clustering Hierarchy Protocol for Wireless Sensor Networks,” Elsevier Journal on Computer Communications, vol. 30, pp. 2842-2852, October 2007.

[24] Xiaorong Zhu, Lianfeng Shen and Tak Shing Peter Yum, “Hausdorff Clustering and Minimum Energy Routing for Wireless Sensor Networks,” IEEE Transaction on Vehicular Technology, vol. 58, no.2, pp. 990-997, February 2009.

[25] Huei Wen Ferng, Robby Tendean and Arief Kurniawan, “Energy Efficient Routing Protocol for Wireless Networks with Static Clustering and Dynamic Structure,” Springer Journal of wireless personal communication (published online), March 2001.

[26] N. Bulusu, J. Heidemann and D. Estrin, “GPS-Less Low-Cost Outdoor Localization for Very Small Devices,” IEEE Personal Communications, vo. 7, no.5, pp. 28–34, 2000.

[27] N. Patwari and A.O. Hero, “Using Proximity and Quantized RSS for Sensor Localization in Wireless Networks,” Proceedings of the 2nd ACM International Conference on Wireless Sensor Networks and Applications (WSNA 2003), NY, USA, 2003.

[28] Lee, J.Y. and Scholtz R., “Ranging in a Dense Multipath Environment Using an UWB Radio Link,” IEEE Journal on Selected Areas in Communications, Vol. 20, no.9, pp. 1677-1683, 2002.

[29] D. Goldenberg, A. Krishnamurthy, W. Maness, R. Yang, A. Young, A.S. Morse, A. Savvides and B.D.O. Anderson, “Network localization in partially localizable networks,” IEEE INFOCOM, vol. 1, pp. 313-326, 2005.

[30] I. Rekleitis, D. Meger and G. Dudek, “Simultaneous Planning, Localization, and Mapping in a Camera Sensor Network,” Robotics and Autonomous Systems, vol. 54, no.11, pp.921–932, 2006.

[31] Haibo Zhang and Hong Shen, “Balancing Energy Consumption to Maximize Network Lifetime in Data-Gathering Sensor Networks,” IEEE Transactions on Parallel and Distributed Systems, vol. 20, no.10, pp.1526-1539, October 2009.

[32] Jiguo Yu, Yingying QI and Guanghui Wang, “An Energy-Driven Unequal Clustering Protocol for Heterogeneous Wireless Sensor Networks,” Journal of Control Theory Applications vol. 9, no. 1, pp. 133-139, February 2011.G. O. Young, “Synthetic structure of industrial plastics (Book style with paper title and editor),” in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

Ashok Kumar is working as Associate Professor in the Department of Electronics and Communication Engineering, National Institute of Technology Hamirpur Himachal Pradesh- INDIA. Presently he is pursuing PhD from National Institute of Technology. His current research areas of interest include wireless communication and wireless sensor networks. He has published more than 20 research papers in International/National journals and conferences in these areas. He is life member of ISTE.

Dr. Narottam Chand received his PhD degree from IIT Roorkee in Computer Science and Engineering. Previously he received M Tech and B Tech degrees in Computer Science and Engineering from IIT Delhi and NIT Hamirpur respectively. Presently, he is working as Associate Professor, Department of Computer Science and Engineering, NIT Hamirpur. He has served as Head, Department of Computer Science & Engineering, during Feb 2008 to Jan 2011 and Head, Institute Computer Centre, during Feb 2008 to July 2009. He has coordinated different key assignments at NIT Hamirpur like Campus Wide Networking, Institute Web Site, Institute Office Automation. His current research areas of interest include mobile computing, mobile ad hoc networks and wireless sensor networks. He has published more than 120 research papers in International/National journals & conferences and guiding six PhDs in these areas. He is member of IEEE, ISTE, CSI, International Association of Engineers and Internet Society.

Dr. Vinod Kapoor was born at Mandi town in Himachal Pradesh, India. He received his BE Degree in Electronics & Communication Engineering from National Institute of Technology (formerly Regional Engineering College), Durgapur, West Bengal, in the year 1987 and Masters Degree in Electronics & Control from Birla Institute ofTechnology & Science, Pilani (Rajasthan) in the year 1996. He did his Ph. D. from Kurukshetra University, Kurukshetra in the field of Optical Fiber Communication in Sept. 2006. He also obtained his MBA degree with specialization in Human Resources Management in the year 2002.He is presently Professor in the Department of Electronics & Communication Engineering NIT Hamirpur, India. He has coordinated different key assignments at NIT Hamirpur like Training & Placement Officer, Chief Warden (Hostels), organizing short term courses. His research interest includes optical fiber communication and optoelectronics/nano devices. He has published more than 30 research papers in International/National journal & conferences and guiding four Ph.Ds in these areas. He is member of ISTE, IETE and IE.