ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 8, August 2015

An Energy Efficient Clustering Algorithm with Adaptive Self-Organization for Wireless Sensor Networks

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Abstract: Wireless sensor networks are an emergent technology for monitoring physical world. The energy constriction of Wireless sensor networks requires energy (resource) saving and so elongating the network lifetime become the utmost imperative goalmouths of numerous routing conventions. Clustering is a strategic technique used to prolong the lifetime of a sensor network by plummeting energy consumption. This research work is taking traditional probabilistic clustering protocol concepts, also considering heterogeneity in wireless sensor network as an effective way to increase the network lifetime and stability. Many issues in Wireless Sensor Networks (WSNs) are formulated as multidimensional optimization problems, and approached through self-organizing concept and load balancing architecture. We are proposing a distributed energy and geographically dynamic clustering scheme with adaptive cluster formation process for efficient routing in wireless sensor network, to make an optimized cluster head selection process and adaptive cluster formation which depends upon current network conditions and resource status. Simulation results show that with this network designing the network lifetime and stability period increases extensively.

Keywords: Wireless sensor network, Energy efficient clustering, Adaptive Self-Organization, routing, Energy Distribution, Network density, Network Lifetime, Adaptive clustering.

I. INTRODUCTION

Wireless Sensor Networks (WSN) typically comprises of low cost nodes having sensors, limited computation facilities, a power module and transmission segment that is accomplished of short radio range communication. The only source of energy is the battery, which is unlikely to be substituted. Hence, energy preservation becomes one of the most imperative encounters in WSNs. WSN nodes are densely deployed and hence non-availability of a scarce of them does not hinder application performance. It should be revealed here that, in some applications, for occurrence, in military applications or applications in medical science such networks are required to be highly unswerving [1].

Much attention has been given to the reduction of unnecessary energy consumption of sensor nodes in areas such as hardware design, collaborative signal processing, transmission power control polices, and all levels of the network stack. However, reducing an individual sensor's power consumption alone may not always allow networks to realize their maximal potential lifetime. In addition, it is important to maintain balance of power consumption in the network so that certain nodes do not die much earlier than others, leading to unmonitored areas in the network [2]-[3].

Previous research has shown that because of the characteristics of wireless channels, multi-hop forwarding between a data source and a data sink is often more energy efficient than direct transmission. Based on the power model of a specific sensor node platform, there exists an optimal transmission range that minimizes overall power consumption in the network. When using such a fixed transmission range in general ad hoc networks, energy consumption is fairly balanced, especially in mobile networks, since the data sources and sinks are typically assumed to be distributed throughout the area where the network is deployed. However, in sensor networks, where many applications require a many-to-one (converge cast) traffic pattern in the network, energy imbalance becomes a very important issue, as a hot spot is created around the data sink, or base station. The nodes in this hot spot are required to forward a disproportionately high amount of traffic and typically die at a very early stage.

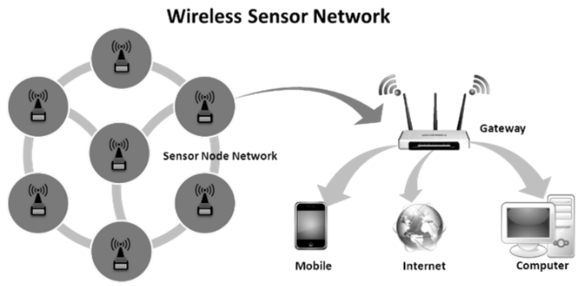

Figure1. Basic architecture of wireless sensor network

One of the well-known mechanisms for improving energy conservation thereby increasing the lifetime in WSN is the use of Clustering technique. Nodes of WSN are divided into a number of groups or clusters. The coordinator of a cluster is known as cluster-head (CH).CHs are assumed to be nodes with comparatively higher energy and so they are used for forwarding (may be after some computation) the data sensed by other low-energy non-CH or member nodes.

 DOI 10.17148/IJARCCE.2015.4831

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
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One of the key challenges of Wireless Sensor Networks (WSN) is the efficient use of limited energy resources in battery operated sensor nodes. Hierarchical clustering [2], [3], [4] has been shown to be a promising solution to conserve sensor energy levels [5] besides being an effective solution to organizational tasks. With Cluster Heads (CH) that act as local controllers of network operations, a clustered WSN has an easily manageable structure.

Each sensor node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a processing unit which can be a small micro-controller, sensing unit, and an energy source, usually an alkaline battery [1]. The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server.

II. BACKGROUND & RELATED WORK

A. Data Transmission assortment Optimization

Early work in transmission range optimization assumed that forwarding data packets towards a data sink over many short hops is more energy efficient than forwarding over a few long hops, due to the nature of wireless communication. The problem of setting transmission power to a minimal level that will allow a network to remain connected has been considered in several studies [6]. Later, others noted that because of the electronics overhead involved in transmitting packets, there exists an optimal non-zero transmission range, at which power efficiency is maximized [7]. The goal of these studies was to find a fixed network-wide transmission range. However, using such schemes may result in extremely unbalanced energy consumption among the nodes in sensor networks characterized by many-to-one traffic patterns. If we define sensor network lifetime as the model presented in [8], which is the network duration until the first node runs out of energy, this unbalanced energy consumption will greatly reduce the network lifetime. An energy efficient routing scheme was proposed in [9]. The objective function of this scheme is to extend network lifetime by routing outgoing traffic intelligently.

B. Sensor arrangement strategies

Several sensor deployment strategies exist that can help extend network lifetime. These strategies include the movement of data sinks [10] the deployment multiple base stations [11] and the formation of data aggregation clusters [12], [13], [14], [15]. However, some of the research related to these strategies has primarily considered the case where the strategies are specifically chosen around the application requirements, while the others have focused only on the feasibility of the proposed solution while ignoring the fact that a more complex sensor deployment scheme may incur a larger financial cost. In this paper, not only do we investigate and compare the performance of each strategy using general terms such as normalized network lifetime, but we also propose some practical sensor deployment strategies from a cost efficient perspective.

Previous problem consider that, the clusters near the base station also forward the data from further clusters, and as we all know, too many members in a cluster may bring about excessive energy consumption in management and communication. Hence, based on the above concerns, DSBCA algorithm [16] considers the connectivity density and the location of the node, trying to build a more balanced clustering structure. If two clusters have the same connectivity density, the cluster much farther from the base station has larger cluster radius; If two clusters have the same distance from the base station, the cluster with the higher density has smaller cluster radius. We are proposing a Distributed Energy and geographically dynamic clustering scheme with adaptive cluster formation process for efficient routing in wireless sensor network, the main intention is to make an optimized cluster head selection process and adaptive cluster formation which depends upon current network conditions and resource status.

III. THE PROPOSED CLUSTERING SOLUTION

In this section we describe our model of a wireless sensor network with nodes heterogeneous in their initial amount of energy. We particularly present the setting, the energy model, and how the optimal cluster heads & clusters can be computed. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. We assume that all nodes are distributed uniformly and randomly over the sensor field.

1. Geographically Dynamic Energy Efficient Clustering (Cluster Head Selection Phase):

We consider a sensor network that is hierarchically clustered. Our proposed algorithm maintains such clustering hierarchy. In our protocol, the clusters are re-established in each “round.” New cluster heads are elected in each round and as a result the load is well distributed and balanced among the nodes of the network. Moreover each node transmits to the closest cluster head so as to split the communication cost to the sink. Only the cluster head has to report to the sink and may expend a large amount of energy, but this happens periodically for each node. In our protocol there is an optimal percentage p_{opt} of nodes that has to become cluster heads in each round assuming uniform distribution of nodes in space. A random field is created and nodes are randomly placed, every node contains a specified amount of energy.

In proposed work, for making global decision, residual energy of each sensor is compared with the average network energy and due to heterogeneity, proposed work also consider initial energy for the selection criteria. The initial energy of sensors are compare with the total network energy. Our aim to maximize stability and lifetime is depend upon the maximum use of more powerful CHs within network. For this we are considering sensors closer to BS and which are in denser area, so that they can collect more data and forward to a lesser distance.

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Total network energy is calculated by summing energies of all sensors and average energy is calculated by the following equation:

$$\boldsymbol{\zeta}_{\text{avg}} = \zeta_t \times \left(\frac{1 - \frac{\tau_{current}}{\tau_{\max}}}{\mathrm{n}_s}\right)$$

As per the formula of average energy, the average energy in network is zero when the current transmission round is equal to maximum number of rounds. Calculation of optimum probability for selection of Cluster Head after the trigger (random) head selection process is

$$\mathbf{P(u)} = \boldsymbol{\beta}_{\mathbf{rand}}(\mathbf{u}) \times \mathbf{n}_s \times \frac{\zeta_{\mathbf{int}}(\mathbf{u})}{\zeta_t(n)} \times \frac{\zeta_{\mathbf{curr}}(\mathbf{u})}{\zeta_{\mathbf{avg}}(\boldsymbol{n})} \times \frac{\boldsymbol{\psi}_{\mathbf{density}}(\mathbf{u})}{\boldsymbol{\xi}_{\mathbf{base}}(\mathbf{u})}$$

Here, **P(u)** is a user defined random probability value between 0 to 1, based upon the optimum solution of our algorithm, $\zeta_{\mathbf{int}}(\mathbf{u})$ initially supplied energy with respect to total energy$\zeta_t(n)$ *and* $\zeta_{\boldsymbol{curr}}(\boldsymbol{u})$iscurrentresource status with respect to average energy in network $\zeta_{\mathbf{avg}}(\boldsymbol{n})$. $\boldsymbol{\psi}_{\mathbf{density}}(\mathbf{u})and\boldsymbol{\xi}_{\mathbf{base}}(\mathbf{u})$are the network density and distance from base station of u_{th}sensor. We also consider that the selection of head also depends upon the number of sensorsn in the network as number of clusters is directly proportional to the number of sensors in network.

NOTE: The best sensor node is selected within the network whose $\frac{\zeta_{int}(\boldsymbol{u})}{\zeta_t(n)}, \frac{\boldsymbol{\psi_{density}(u)}}{\boldsymbol{\xi_{base}(u)}}$ and $\frac{\zeta_{curr}(\boldsymbol{u})}{\zeta_{avg}(\boldsymbol{n})}$ ratio is high.

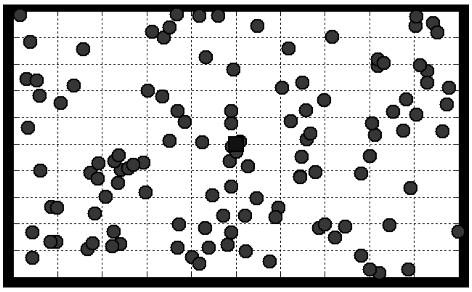

Figure 2.Node placement in network environment and base station placed at the centre of field (for 100 sensors placed randomly in the field of 10000 meter square area)

If the random number is less than a threshold T(u) then the node becomes a cluster head in the current round. The threshold is set where; r is the current round number (starting from round 0.) The election probability of nodes u Є G to become cluster heads increases in each round in the same epoch and becomes equal to 1 in the last round of the epoch. Note that by round we define a time interval where all cluster members have to transmit to their cluster head once. We show in this paper how the election process of cluster heads should be adapted appropriately to deal with *heterogeneous* nodes, which means that *not* all the nodes in the field have the same initial energy. Let, *Temp*= a temporary random number (0 to 1) allotted to every node. A sensor should select as head,

$$\text{If } Temp <= T(u)$$

$$\text{Where,T(u)} = \begin{cases} \frac{\mathbf{P}\,(\mathbf{u})}{1-\mathbf{P}\,(\mathbf{u})\left(\mathrm{r} \bmod \frac{1}{\mathbf{P}\,(\mathbf{u})}\right)} & \text{if } \mathrm{u} \in \mathrm{G} \\ 0 & \text{otherwise} \end{cases}$$

2. Adaptive Self-Organization (Cluster building phase):

Previous work have studied either by simulation or analytically the optimal probability of a node being elected as a cluster head as a function of spatial density when nodes are uniformly distributed over the sensor field. This clustering is optimal in the sense that energy consumption is well distributed over all sensors and the total energy consumption is minimum. Here every node compares its distance from the selected cluster head based on distance vector calculation and decides which head node or cluster to join to transmit its data.Such optimal clustering highly depends on the energy model we use.For the purpose of this study we use similar energy model and analysis as proposed in[15]. According to the radio energy dissipation model, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an L-bit message over a distance *d*, the energy expended by the radio is given by:

$$E_{T2}(l,d) = \begin{Bmatrix} L.E_{elec} + L.\epsilon_{fs}.d^2 \;\; if\ d \le d_0 \\ L.E_{elec} + L.\epsilon_{mp}.d^4 \;\; if\ d > d_0 \end{Bmatrix}$$

Here E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model we use, and *d* is the distance between the sender and receiver. By equating the two expressions at $d = d_0$, we have$d_0 = \sqrt{\epsilon_{fs}/\epsilon_{mp}}$. To receive an L-bit message the radio expends $E_{Rx} = L.E_{elec}$.This radio model will help us to calculate the amount of dissipated energy after every round based on distance vector based calculation.

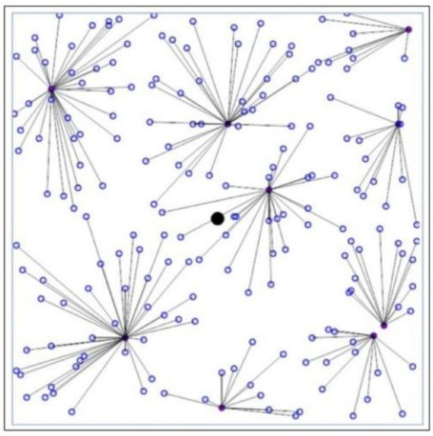

Figure 3.Selection of the next CHs towards balancing the cluster size. The selection is adaptive and depends upon the network density of WSN.

3.Procedural Steps:

First section is network initialization, in this phase we have to decide the network parameters, like field area, number of devices, device parameters. The routing is based on distance vector, means we have to make communication between our network devices through calculation of distance vector in hop by hop manner (Node to Node communication is based on distance vector and

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
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node to cluster head communication is also based on distance vector) For this, first of all we have to calculate distance vector between network devices based on their position, and path is calculated according to these distance vectors values.

After the initialization and setup phase completed, the transmission phase is started, in this phase, initially we calculate and update the energy values of every device and it will update at every transmission round. First thing to start a transmission round is the selection of cluster head, we defined a criteria based on geographical parameters such as distance from base station, overall network density and energy parameters like residual (current) energy of node, initial energy of node, average energy of network, and the total energy of the network. The considered network parameters are shown in table below.

Table I: Parameter settings of the first-order radio model

Parameters	Values
Initial energy (*E0*)	0.5 J/node
Transmitter Electronics (*Eelec*)	50 n J/bit
Receiver Electronics (*Eelec*)	50 n J/bit
Data Packet Size (*l*)	4000
Transmitter Amplifier (εfs) if $d \leq d0$	10 pJ/bit/m^2
Transmitter Amplifier (εmp) if $d \geq d0$	0.0013 p J/bit/m^4

After the selection of cluster head, a cluster region is created around the particular cluster head, and nodes belonging to that region are labelled as cluster members. In transmission phase, the Cluster members transmit their data to cluster head and cluster head transmit the collected data to the destination directly. The Clustering and routing procedure continues till the network devices are alive, the devices with a proper energy levels are selected as cluster head one after another every round. In case of research work in wireless network, system efficiency can be calculated from the relation of input and output data packets. Hence the throughput, end to end delay and network lifetime are the best suited parameters to show research efficiency.

IV.RESULTS

This work Method is applied in a Sensor Field of Area 100×100 m. However one can change the field area as per the result variations. Also, the base Station is Placed at the Centre of Sensor Field initially, however we can change the Position of base Station.Initially the dissipated energy is Zero & residual energy is the Amount of initial energy in a Node, Hence Total energy $E_t$is also the Amount of residual energy of all the sensors because it is the sum of dissipated & residual energy. Simulations are carried out in **MATLAB**.

After starting a round, firstly it checks if there is a dead node in the Sensor Field, and repeats these criteria after every round. After a Cluster Head send its Data to Sink, Energy dissipated is calculated, through energy models considered in the propose work, in order to calculate how much energy dissipated after a steady state and whether a Cluster head is eligible to transmit data in the next round too. The 100 Nodes are placed in the randomly manner in the whole field, the number of clusters directly depends upon the number of cluster head. A single cluster head is assigned to clusters which act as a sub-destination and route data from other cluster member nodes to the destination (Sink or Base Station).

The distance vector calculation is a very important process while developing a communication protocol for sensor network, as energy is directly dependent to distance, so it is necessary for a system to calculate the distance between all sensor devices with each other. Let assume that the node position in the cell is (x_n, y_n). It can be defined the distance between node i and the other node (x_c, y_c) as:

$$D_{[i]} = \sqrt{(x_c - x_n)^2 + (y_c - y_n)^2}$$

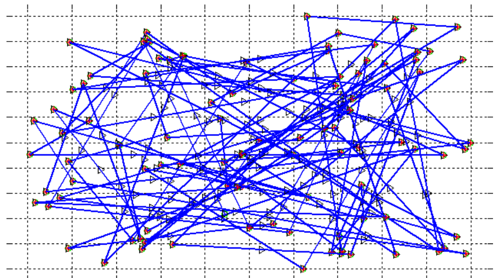

Figure 4.It shows the distance vector calculation between different sensor devices. This distance information is very useful for data communication based on distance in case of energy saving schemes.

Throughput of receiving bits:It is the ratio of the total number of successful packets in bits received at the sink or base station in a specified amount of time.

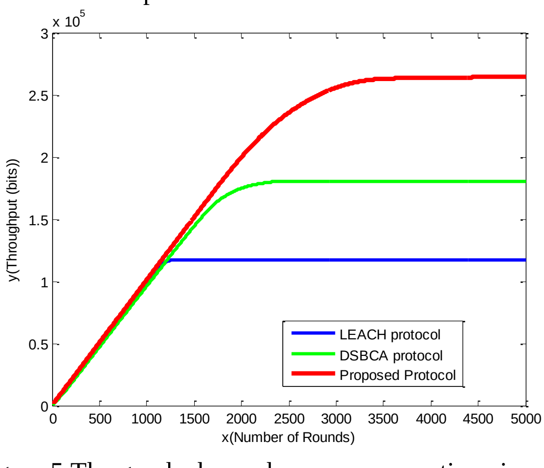

Figure 5.The graph above shows a comparative view of obtained network throughput from the proposed scheme, the LEACH [14] and DSBCA [16] Protocols.

The throughput obtained with respect to number of rounds or communication period. It is measured in terms of bits/second. Although, the base station received the data in terms of packets, a single packet consist of 8 bits of data. Above experiment are done for 100 sensor nodes in the field area. It is clear from the figure that, in proposed approach a throughput of approximately 262000 bits is calculated which much higher than the approach proposed by LEACH [14] and DSBCA [16]Protocols.

In Proposed model, a Node will become Cluster Head, if a Temporary number (between 0 to1) assigned to it is less

 DOI 10.17148/IJARCCE.2015.4831

than the Probability Structure. Hence, only the nodes with higher weight amongst the other nodes can fulfil the criteria above and hence a node can transmit data as a cluster head for a longer period which results in increment of network lifetime and throughput. After a higher weight node becomes Cluster Head, Energy Models are applied to calculate the Amount of Energy Spent by it on that Particular Round and complete the round of steady state phase. When this dissipated energy is subtracted from the initial energy, then the amount of energy remain is called residual energy. When a node residual energy is zero then the node is called dead and is terminated from the network environment. The statistics of dead nodes with respect to transmission rounds is shown in figure below:

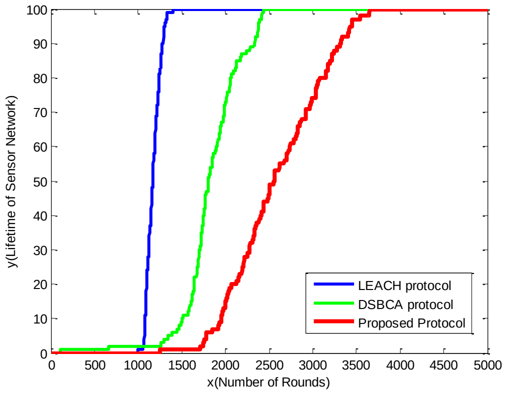

Figure 6.Figure above shows a comparative view of death of sensor nodes with each round for the proposed scheme, the LEACH [14] and DSBCA [16] Protocols.

Node dead statistics are obtained with respect to number of rounds or communication period. Above experiment are done for 100 sensor nodes in the field area.Result is taken when the base station is placed at the centre of sensor field and the selection probability is defined through the energy values considered. It is clear from the figure that both the network lifetime and stability of lifetime of network is achieved through proposed protocol. Also, it was observed that the technique network proposed in LEACH [14] and DSBCA [16] Protocols completely stopped functioning at an earlier simulation rounds compared to our proposed technique. We saw that the functional capacity for LEACH [14] and DSBCA [16]Protocols created network lasted till an estimated value of ~1400 and ~2500 rounds of simulation, while the functional capacity of the proposed approach lasted till an estimated value of ~3700 rounds of simulation.

In Fig.7, The graph obtained shows a comparative view of end to end delay measured at the base station or delay introduced by the routing scheme in delivering data packets to the base station from the proposed scheme, the LEACH [14] and DSBCA [16]Protocols. The End-to-end delay obtained with respect to number of rounds or communication period. It is measured in terms of milliseconds. Above experiment are done for 100 sensor nodes in the field area. It is clear from the figure that, in proposed approach the end-to-end delay is much lower and about 0.022 which is lower than the approach proposed by LEACH [14] and DSBCA [16]Protocols.

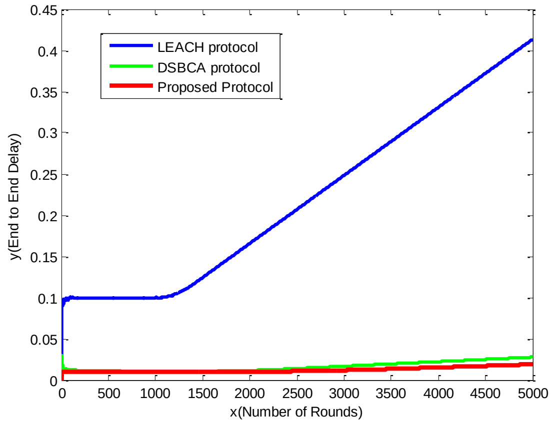

Figure 7.End-to-End Delay is the delay that could be caused by buffering during route discovery, queuing delays at interface queues, retransmission delays at the media, and propagation and transfer times.

Table II. Comparisons of network lifetimes (number of rounds)

NODES	PROTOCOL	NODES DEAD (in Rounds)	
		10%	100%
100	LEACH Protocol	1080	1396
	DSBCA Protocol	1500	2434
	Proposed Methodology	1950	3653

This section conclude that and also here results shows that, this protocol successfully extends the stable region to more than 2000 rounds by being aware of heterogeneity through assigning probabilities of cluster-head election weighted by the relative initial energy and geographical position of nodes, also the lifetime of network extended to more than 3500 rounds in this protocol.

V. CONCLUSION

Many problems are considered from previous work including, the self-organizing concept, weight for selection of head etc. This work proposed “An Energy Efficient Clustering Algorithm With Adaptive Self-Organization for Wireless Sensor Networks”, which is further compared by Load-Balanced Clustering Algorithm With Distributed Self-Organization for Wireless Sensor Networks proposed in [16]. This protocol is used to determine the optimal probability for cluster formation in WSNs. Simulation results show that in terms of network lifetime of sensor node. The use of the optimal probability yields optimal energy-efficient clustering.

Results shows that, this protocol successfully extends the stable region to more than 2000 rounds by being aware of heterogeneity through assigning probabilities of cluster-head election weighted by the relative initial energy of nodes, also the lifetime of network extended to more than 3500 rounds in this protocol.

Proposed algorithm is implemented using MATLAB and tested multiple times and results are satisfactory.

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 8, August 2015

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, Wireless sensor networks: a survey, Computer Networks 38 (2002) 393–422.
[2] A. A. Abbasi and M. Younis, “A survey on clustering algorithms for wireless sensor networks,” Computer Commun., vol. 30, pp. 2826–2841 , 2007.
[3] S. Bandyopadhyay and E. J. Coyle, “An energy efficient hierarchical clustering algorithm for wireless sensor networks,” in Proc. INFOCOM, Mar. 2003, pp. 1713–1723.
[4] L. Qing, Q. Zhu, and M. Wang, “Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks,” Computer Commun., vol. 29, pp. 2230–2237, 2006.
[5] M. Younis, M. Youssef, and K. Arisha, “Energy-aware management for cluster-based sensor networks,” Computer Networks, vol. 43, pp. 649 – 668, 2003.
[6] R. Ramanathan and R. Hain, “Topology control of multihop wireless networks using transmit power adjustment,” in Proceedings of the Nineteenth International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), 2000.
[7] J. Deng, Y. Han, P. Chen, and P. Varshney, “Optimum transmission range for wireless ad hoc networks,” in Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), 2004.
[8] J.-H. Chang and L. Tassiulas, “Energy conserving routing in wireless ad-hoc networks,” in Proceedings of the Nineteenth International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), 2000.
[9] G. Zussman and A. Segall, “Energy efficient routing in ad hoc disaster recovery networks,” in Proceedings of the Twent Second International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), 2003
[10] A. Kansal, M. Rahimi, D. Estrin, W. Kaiser, G. Pottie, and M. Srivastava, “Controlled mobility for sustainable wireless sensor networks,” in Proceedings of The First IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks (SECON), 2004.
[11] S. R. Gandham, M. Dawande, R. Prakash, and S. Venkatesan, “Energy efficient schemes for wireless sensor networks with multiple mobile base stations,” in Proceedings of the Global Telecommunications Conference (GLOBECOM), 2003.
[12] S. Lindsey, C. Raghavendra, and K. Sivalingam, “Data gathering algorithms in sensor networks using energy metrics,” IEEE Transactions on Parallel and Distributed Systems, vol. 13, pp. 924–935, Sept. 2002.
[13] O. Younis and S. Fahmy, “HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks,” IEEE Trans. Mobile Comput., vol. 3, no. 4, pp. 366–379, Dec. 2004.
[14] W. R. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, “Energy efficient communication protocol for wireless micro sensor networks” in Proc. 33rd Annu. Hawaii Int. Conf. Syst. Sci., Jan. 2000, pp. 1–10.
[15] W. R. Heinzelman, “An application-specific protocol architecture for wireless microsensor networks,” IEEE Trans. Wireless Commun., vol. 1, no. 4, pp. 660–670, Oct. 2002.
[16] Ying Liao, Huan Qi, Weiqun Li, “Load-Balanced Clustering Algorithm With Distributed Self-Organization for Wireless Sensor Networks ”, IEEE SENSORS JOURNAL, VOL. 13, NO. 5, MAY 2013.