

Energy Proficient Rendezvous Scheduling with Mobile Sink using Compressive Sensing in Wireless Sensor Networks

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Abstract

Background/Objectives: Energy efficiency and optimization of battery resources are the most important design standards for the wireless sensor networks. **Methods:** Using Compressive sensing the number of transmissions of sensor nodes is reduced thereby using the battery resources of the sensor node efficiently. In this paper, a cluster-based hybrid method is proposed using compressive sensing with mobile sink, which collects data periodically along the predefined path and uploads data to its respective relay nodes which further communicates the information to the collection head. The data is transmitted to the nearest rendezvous node in a certain number of rounds depending on the compression ratio; after undergoing compression at individual cluster heads. The main reason for the extended lifetime of this network is the reduction in the number of transmissions and the reduced transmission range of nodes. **Findings:** Investigation a lout comes display that the proposed algorithm can considerably out class numerous prevailing procedures with high stability and good energy efficiency. **Improvements:** The stability of the proposed algorithm is increased and holds good even when the area of the region increased with the lowest rate of energy dissipation.

Keywords: Base station (BS), Clustering, Cluster Head (CH), Compressive Sensing (CS), Mobile Sink (MS), Rendezvous Node (RN), Wireless Sensors Networks (WSN)

1. Introduction

The new and recent advances in technology of microelectronic have made it possible to build solid and cheap wireless sensors^{1,2}. So Systems which is formed by these sensors are called as Wireless Sensor Networks (WSNs), have been getting note worthy consideration owing to their prospective applications in intelligent building, health care, military operations² etc. In such network, the sensor nodes are inter connected with each other and gather the information and handover it to the sink node or to the gateway either directly or in a multi-hop fashion. The main constraint of sensor nodes, however, is their low finite battery energies, computational power, memory efficiency, which bounds the system lifespan and power on the value of network^{2,3}. Many routing protocols have been proposed so as to increase energy efficiency in WSNs. Routing protocols in this are generally classified

into two types. They are network structure protocols and protocols based on operation⁴. Network structure protocols are further classified into three types: flat structure protocol, cluster based protocols and location based protocol⁵. Among these categories, the most energy efficient ones are the cluster-based routing protocol which is the focal point in this paper. Low Energy Adaptive Clustering Hierarchy (LEACH)^{6,7} is a self-organizing and adaptive clustering protocol with distributed cluster formation for WSNs. For reducing collision in inter-cluster and intra cluster LEACH uses Time Division Multiple Access (TDMA) and CDMA MAC protocols. Standard Evaluation Protocol (SEP)^{8,9} is a hierarchical network with two levels of heterogeneity where the high energy nodes are known as advanced nodes and have a greater probability of becoming CHs as compared to the non-advanced nodes. The drawback of SEP is that the election of CHs is not dynamic which results in uneven energy

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consumption⁹. Distributed Energy-Efficient Clustering (DEEC)¹⁰ protocol uses the early and remaining energy of nodes for defining the CHs.

Hybrid Energy Efficient Distributed (HEED)¹¹ is a scattered procedure which stochastically selects the cluster heads. The cluster heads is elected based on their cluster election probability. Enhanced Distributed Energy-Efficient Clustering (EDEEC)¹² protocol spreads the idea of heterogeneity to three energy levels by adding the perception of super nodes to the already existing normal and advanced nodes.

Threshold Sensitive stable Election Protocol (TSEP)¹³ is a reactive routing protocol with three levels of heterogeneity. Cluster head is selected on the basis of a predefined threshold. It increases the period of stability and network lifetime. The proposed algorithm is a hybrid that utilizes the benefits of clustering, sink mobility, compressive sensing and data gathering using rendezvous node. A four level heterogeneous network is taken into account to maximize the network efficiency. The detailed algorithm is defined in the following section.

2. Four Level Heterogeneous WSN Model

A wireless networks in which the nodes have different initial energies are termed as heterogeneous network. In this paper, four different energies level of nodes are considered². The nodes are classified as ordinary, progressive, great and high-end nodes based on their initial energies. The initial energy of normal node is E_0 . The total numbers of these nodes are calculated as given in the following equations¹⁴

$$TotalNum_{ultrasuper} = Nm_1 \quad (1)$$

$$TotalNum_{super} = Nm_0 \quad (2)$$

$$TotalNum_{advanced} = Nm \quad (3)$$

$$TotalNum_{normal} = N(1 - m_1 - m_0 - m) \quad (4)$$

Where N is the overall number of sensors in the network². Initial energy of the ultra-super nodes, super nodes, advanced nodes and normal nodes are calculated as shown below¹³:

$$E_{ultrasuper} = Nm_1 E_0 (1 + u) \quad (5)$$

$$E_{super} = Nm_0 E_0 (1 + b) \quad (6)$$

$$E_{advanced} = Nm E_0 (1 + a) \quad (7)$$

$$E_{normal} = N E_0 (1 - m_1 - m_0 - m) \quad (8)$$

The total initial energy is given by the following^{1,13}

$$E_{total} = E_{ultrasuper} + E_{super} + E_{advanced} + E_{normal} \quad (9)$$

$$E_{total} = Nm_1 E_0 (1 + u) + Nm_0 E_0 (1 + b) + Nm E_0 (1 + a) + N E_0 (1 - m_1 - m_0 - m) \quad (10)$$

3. Proposed work

The proposed work overcomes the limitations of the previous algorithms associated with Heterogeneous Wireless Sensor Networks (HWSNs). It further enhances the lifetime and stability period of the WSN when compared to other techniques such as SEP, DEEC, TSEP and EDEEC. In this algorithm, the sensors are classified into four groups of different power levels ensures a good stability period for the network^{15,16}.

The algorithm starts with the specification of the network simulation parameters and the creation of a random sensor network; where the nodes are scattered randomly over the network with four energy levels. Among these nodes, a few advanced energy level nodes are selected as rendezvous nodes to create the traversal path for the mobile sink for data gathering in the network. These nodes are selected on the basis of the following criterion:

$$\text{if } \frac{y_m}{2}(1 - R_x) \leq y_i \leq \frac{y_m}{2}(1 + R_x) \quad (11)$$

→ Type = RN

Where R_x is a random number between 0 and 1, y_i is the y-coordinate of the node and y_m is the vertical dimension of the network. The optimal number of clusters¹⁷ (k_{opt}) is determined in accordance to the protocol which is given by:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d_{toBS}^2} \quad (12)$$

where, d_{toBS} : distance between CH and BS,
 N : number of nodes deployed in region M^2 .

$$d_{toBS} = 0.765 \frac{M}{2} \quad (13)$$

The region is divided into grids; where each grid represents a cluster. For each grid, a unique cluster head is chosen by the method employed for cluster head selection¹⁵ in the LEACH protocol. The rendezvous nodes are excluded from this step. Based on the middling energy of the system in each iteration¹⁴, the cluster election probability p_i of each node is calculated as per the Improved Balanced Energy Efficient Network Integrated Super Heterogeneous (iBEENISH) protocol^{12,13}:

$$p_i = \left(\frac{((p_i^{opt}) E_i(r)) / ((1 + m(a + m_1 0 (-a + b + m_1 1 (-b + u))) \cdot E(r)) @ \text{for normal node if } E_i(r) > T_{absolute} @ (p_i^{opt} (1 + a) E_i(r)) / ((1 + m(a + m_1 0 (-a + b + m_1 1 (-b + u))) \cdot E(r)) @ \right) \quad (14)$$

where, $T_{absolute} = z * E_0$ and $z=0.71$.

Intra-Cluster Transmissions

After the selection of cluster heads for each cluster, each grid is further divided into sub-grids with a proportion similar to their parent grids. Each sub-grid in an individual cluster is taken as a sub-cluster and a relay node is chosen for each sub-cluster based on the following criterion:

$$w = \frac{\gamma}{E_{res}} + \frac{1-\gamma}{v} \sum_{i=1}^v (d_i - d_{iCH})^2 \quad (15)$$

where v : number of nodes in the sub-cluster;

γ : weighted variable¹⁸;

E_{res} : residual energy of cluster head associated with the parent cluster.

d_i : Remoteness among nodes;

d_{iCH} : Remoteness among the node and the group head.

The node with smallest value of w in that sub-cluster is taken as the relay node of that sub-cluster. The nodes transmit their data to the associated relay nodes which further forward the data to their cluster head as shown in Figure 1. At the cluster head, the data is aggregated and compressed with a specific compression ratio C_r , and then transferred to the nearest rendezvous node¹⁹. The data is accumulated at the rendezvous nodes from various cluster heads as shown Figure 2 and the mobile sink gathers data periodically from them during the course of its traversal among the rendezvous nodes in the whole region. Figure 3 gives the pseudo code of the proposed algorithm.

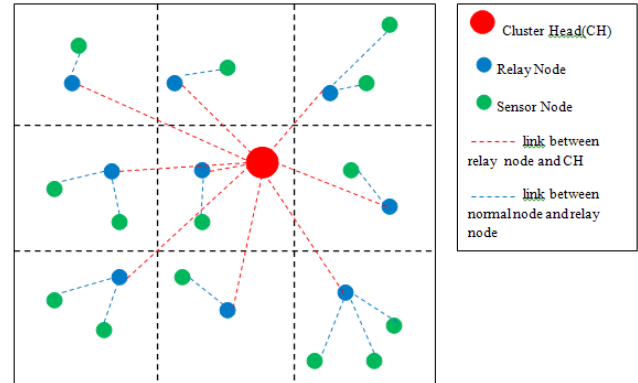


Figure 1. Intra-cluster topology

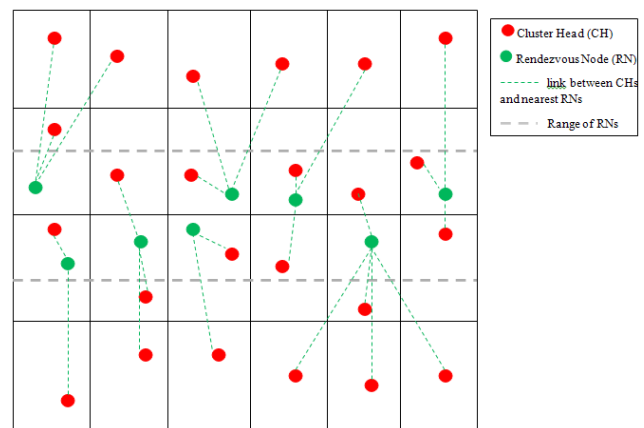


Figure 2. Network Topology

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Create a random sensor network with normal, advanced, super and ultra-super nodes.
for all nodes 1: n
    if node type == 'advanced'
        if  $\frac{y_m}{2} (1 - R_x) \leq y_i \leq \frac{y_m}{2} (1 + R_x)$ 
            Node is a rendezvous node
Divide the region into grids (clusters).
for all rounds 1:  $r_{max}$ 
    if  $(r \bmod M) == 1$ 
        Select cluster heads for all grids as per their election probability.
    for each cluster
        Divide the cluster into sub-clusters (sub-grids).
        for each sub-cluster
            Select a relay node
            Transmit data from nodes to relay node
        if  $(r \bmod M) \sim 1$ 
            Transfer data from all relay nodes to cluster heads.
            Compress data at cluster head.
            Transfer M projections of data from cluster head to nearest rendezvous node for next M rounds.
Move mobile sink to each rendezvous node and collect data.

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Figure 3. Pseudo code for proposed algorithm

4. Simulation Results and Discussion

In this section, the routine of the proposed procedure is analyzed and compared with the existing protocols SEP, DEEC, EDEEC and TSEP using MATLAB. The valuation is completed by seeing the stability period, number of live nodes and the residual energy of the network^{1,11,13}. Table 1 projects the simulation parameters.

Figure 4(a), 4(b) and 4(c) show the number of live nodes against the number of rounds for all the scenarios. They show that the stability period of the proposed algorithm is better than the existing protocols.

For the first scenario, the first node of SEP, DEEC, EDEEC, TSEP and proposed algorithm dies at 1652, 1024, 1114, 2028 and 2584 rounds respectively. For the second scenario, the first node of SEP, DEEC, EDEEC, TSEP and proposed algorithm dies at 1006, 1244, 362, 1369 and 3623 rounds respectively. For the third scenario, the first node of SEP, DEEC, EDEEC, TSEP and proposed algorithm dies at 1253, 624, 214, 674 and 2709 rounds respectively.

Table 1. Simulation Parameters^{1,4,11,13}

Parameters	Value
Region Dimensions	100 * 100 m ² , 200 * 200 m ² and 300 * 300 m ² .
Number of nodes	300, 600, 800
Initial Energy (E_0)	0.5 J
Energy consumed by radio electronics in transmit mode (E_{Tx})	50 nJ/bit
Energy consumed by radio electronics in receiving mode (E_{Rx})	50 nJ/bit
Energy consumed by the power amplifier on the free space model (E_{fs})	10 pJ/bit/m ²
Energy consumed by the power amplifier on the multi path model (E_{amp})	0.0013pJ/bit/m ²
Energy consumed for data aggregation (E_{DA})	5 nJ/bit/signal
Optimal cluster head selection probability (P_{opt})	0.1
Data packet size (L)	4000 bits

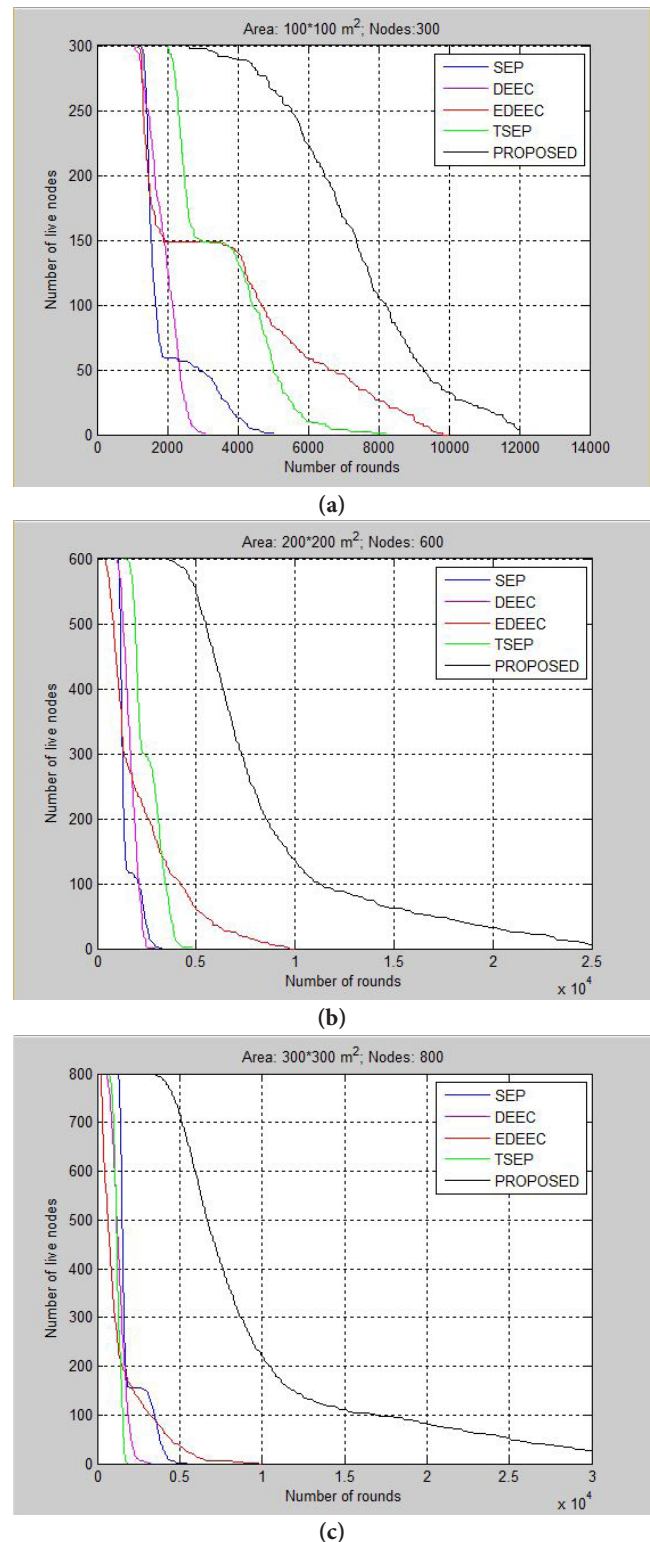


Figure 4 (a). Number of live nodes vs. number of rounds for area 100 × 100 m² with 300 nodes (b). Number of live nodes vs. number of rounds for area 200 × 200 m² with 600 nodes (c). Number of live nodes vs. number of rounds for area 300 × 300 m² with 800 nodes

For the first scenario, the above analysis shows that in terms of stability, the proposed algorithm is 1.6 better than SEP, 1.5 better than DEEC, 2.4 times better than EDEEC and 1.3 better than TSEP. For the second scenario, the above analysis shows that in terms of stability, the proposed algorithm is 3.6 times better than SEP, 3 times better than DEEC, 10 times better than EDEEC and 2.6 times better than TSEP. For the third scenario, the above analysis shows that in terms of stability, the proposed algorithm is 2 times better than SEP, 4.3 times better than DEEC, 12.5 times better than EDEEC and 4 times better than TSEP.

Figure 5(a), 5(b) and 5(c) shows the remaining energy of the system against the number of rounds for all the three scenarios. The initial residual energies of the protocols are different because of the different levels of heterogeneity. Hence, the proposed algorithm has been assessed and compared with the other protocols based on the degree of energy degeneracy.

Figure 6, displays the graphical depiction of the remaining energy (in joules) next 1000 rounds for diverse situations. It can be concluded from the above figures that the rate of energy dissipation in the proposed algorithm

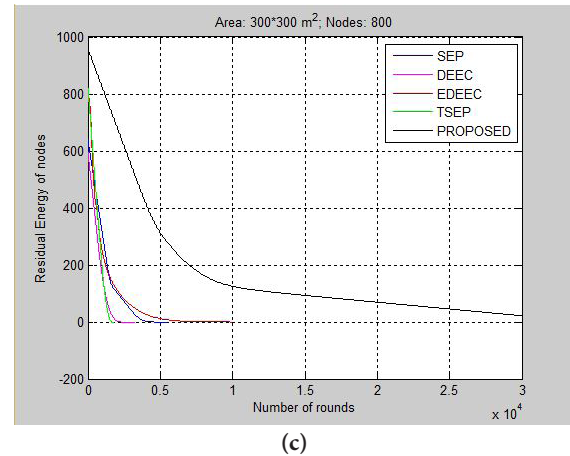
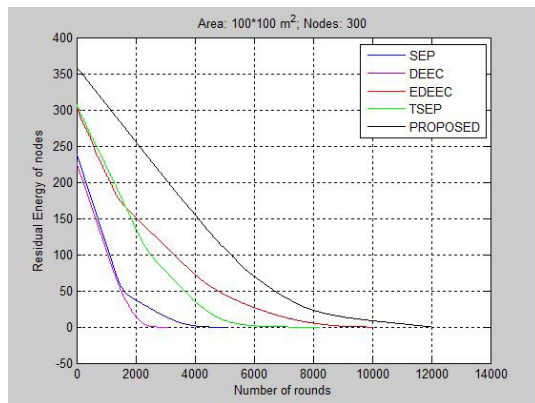
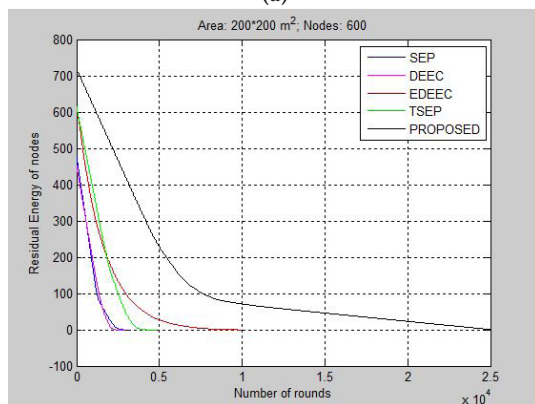


Figure 5 (a) Residual energy vs. number of rounds for area $100 \times 100 \text{ m}^2$ with 300 nodes (b) Residual energy vs. number of rounds for area $200 \times 200 \text{ m}^2$ with 600 nodes (c) Residual energy vs. number of rounds for area $300 \times 300 \text{ m}^2$ with 800 nodes



(a)



(b)

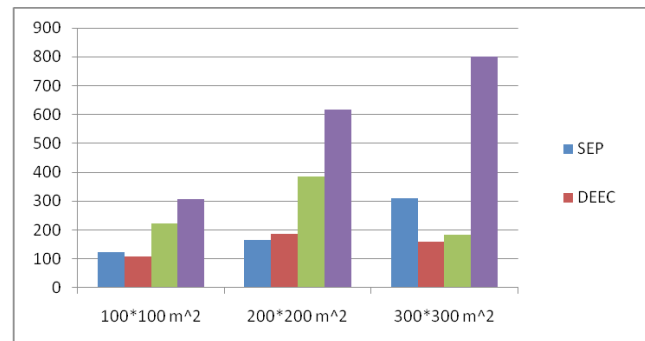


Figure 6. The residual energy (in joules) in after 1000 rounds for different scenarios

in all the three scenarios is the lowest among all the protocols. This is because the data is compressed at the cluster heads and only a small number of projections of the collected data is sent to the rendezvous nodes. The data is then collected by the mobile sink and reconstructed into its original form through the L1-norm algorithm²⁰.

5. Conclusion

In this paper, the data is collected by the sensor nodes and transmitted to the cluster heads through their respective relay nodes. The compressed data is transferred by the cluster head to the nearest rendezvous nodes in a certain number of rounds, depending upon the compression ratio. Finally, the mobile sink gathers the data while moving through the rendezvous nodes in the network.

Experimental proved that stability period of the projected network is much improved than the existing procedures.

The suggested algorithm is 1.6 times better than SEP, 2.5 times better than DEEC 2.4 times better than EDEEC and 1.3 times better than TSEP in a 100m×100m region.

Hence, the protocol results as follows:

1. The number of communications is condensed due to compressive sensing;
2. The broadcast area of cluster heads is condensed due to the introduction of engagement nodes in the network
3. The transmission range of normal nodes is reduced by introducing relay nodes in every cluster for intra-cluster transmission.

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