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Energy Efficinet Cluster Head Selection and Data Convening in Wireless Sensor Networks

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Abstract:

Objectives: Wireless Sensor Network (WSN) contains several distributed sensor nodes. Those nodes are limited in power. Recharging the battery of the sensor node is considered to be a difficult task. The key intent of this paper is to achieve better energy efficiency in WSNs. **Methods/Analysis:** In this paper, an Energy Efficient Cluster Head selection and Data Convening (EECHDC) is proposed in WSNs. Cluster Head (CH) selection is based on residual energy, connection density, capability of the node and degree of the node. **Findings:** The EECHDC scheme has proved better performance in terms of packet delivery rate, packet loss rate, delay, throughput and residual energy during data transmission. **Application/ Improvements:** Simulation results show that the EECHDC achieves higher energy efficiency compared to the existing schemes.

Keywords: Capability, Cluster Head, Connection Density, Degree, Residual Energy, Wireless Sensor Network

1. Introduction

Wireless Sensor Network (WSN) consists of large number of static nodes that are able to interface with each other for transferring data more proficiently and autonomously[1]. It is a growing field with more number of applications. It is used for several environmental applications that extends to military applications and health related applications. The process of dividing the entire communication network into interconnected sub-structures is called clusters. In each cluster, a particular node is elected as the Cluster Head (CH). The CH is selected based on a specific or a combination of metrics such as identity; mobility; degree; density; weight etc. In the network, the CH plays the coordinator role within its substructure. All CHs communicates with other CHs and within its cluster each CH acts as a temporary base station. However CH must be able to communicate with the nodes of other clusters which can be directly or through the respective CH or through gateways. Communication is done in three steps. Initially the CH receives the data sent by its members. Next it compresses the data and finally transmits the data to the Base Station (BS) or other CH. Suitable CH can reduce the utilization of energy and enhances the network lifetime.

One CH per cluster must be selected during an election process, because multiple CHs within a single cluster can give rise to cluster reformation, Quality of Service (QoS) and routing management issues.

The key contributions of EECHDC are as follows:

- The design of a novel Cluster Head (CH) selection algorithm in WSNs, that selects the CHs to create a connected network.
- Performing extensive simulation experiments to calculate the performance of EECHDC algorithm by means of several metrics.

The various existing methods are described as follows:

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol[2] is a cluster based protocol that has involved its energy efficiency, load balancing properties and simplicity. This protocol organizes the nodes into clusters with one node from each cluster serving as a CH and the rest of the node as cluster members. The LEACH protocol

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arbitrarily selects fixed nodes as CH. The CHs gathers the data from their cluster members and combined it before sending it to the other CHs or BS. The cluster construction step is repeated after drop of time so that different nodes are given aopportunity to become CHs.

Power Efficient Gathering in Sensor Information System[3] (PEGASIS) that has an enhancement over LEACH protocol. In PEGASIS, each node intercommunicates only with the closest adjacent and transmitting to the BS, thus minimizing the amount of energy exhausted per round. Using greedy algorithm, the nodes are structured to form a chain. After that the BS can compute this chain and broadcast it to all the sensor nodes in the network. The PEGASIS is better than LEACH by restricting the number of transmissions and removing the overhead of dynamic cluster formation.

Load-Balanced Clustering Algorithm with Distributed Self-Organization for WSNs[4] (DSBCA), a load balanced clustering algorithm deals the stochastic distribution of sensor nodes. This algorithm generates balanced clusters. The radius of the cluster can be determined by the density and the distance from the BS. With farther distance from the BS and lower connectivity density the cluster radius is larger. Each member in the cluster calculates its weight. The node with highest weight is taken as the CH. Weight is calculated based on residual energy, number of neighbors and the number of times the node was elected as CH. DSBCA also limits the number of nodes in a cluster. The main drawback is that it consumes more energy for communication and also it takes more time for calculating weight during CH selection.

A clustering based technique for data monitoring[5] in WSNs is an event driven clustering technique that reports data only when an event occurs. In this technique, a threshold is set and the sensors data with significant change more than the threshold are transmitted to the BS. Upon the detection of an event the sensors are grouped into clusters and one sensor was selected as CH and that will send data to BS in the network. The drawback is that it is not suitable for applications which require continuous monitoring.

A new clustering based on K-means algorithm[6] was used to form the clusters based on Euclidean distances between nodes. This algorithm selects k-nodes randomly as CHs. According to the Euclidean distance, nodes decide its CH. The centroid of the cluster is thus calculated. A node which is near to the centroid will be taken as new CH and then it does reclustering based on the new CH in the network. This approach minimizes the energy consumption for the sensor nodes to send data to the CH. But this K-means algorithm spends most of the time in clustering and reclustering process and thus leads to greater energy consumption.

A Mobility Prediction Based Clustering (MPBC) scheme for Ad Hoc Networks[7] involves the relative mobility of nodes as a criterion in the CH selection. The nodes with low mobility as selected as CHs because they provide more stability in the network. A Flexible Weighted Clustering Algorithm based on Battery Power[8] (FWCABP) for MANETs was proposed to maintain stable clusters by preventing nodes with low battery power from being elected as a CH. This minimizes the number of clusters and the communication overhead of the network.

A grid clustering routing protocol for WSN[9] (GROUP) provides efficient and scalable data packet routing for WSNs. In this protocol, the CHs are arranged in a grid manner and sink energetically and arbitrarily establish the cluster grid. Greed Seed (GS) is a node within a given communication range from the sink. The queries from sink to nodes are propagated from GS to its CHs.

Enhanced LEACH-R[10] introduced the energy efficiency clustering algorithm for WSN that is based on Low Energy Adaptive Clustering Hierarchy. In this protocol contain both the advance and normal nodes, though the advance nodes have more energy than the normal nodes. This protocol improves the regions of cluster based hierarchical process using heterogeneity parameters.

A hierarchical routing algorithm with high energy efficiency named EECA[11] is constructed by using distance and residual energy. For cluster construction, the first step is to elect a cluster head. Therefore distance and residual energy of all nodes is calculated in a one hop neighbor who helps to select cluster head by using CH rotation. From those results, new CH would be elected. The main objective is to reduce the consumption of energy in its application.

The main objective of this paper is to balance the load among the dissimilar clusters in the network such that lifetime of the network is improved by using Load Balanced Clustering Algorithm (LBCA). In LBCA[12], the nodes are grouped into clusters such that network is controlled by the gateway instead of CH. This enhances the performance of the network. Load Balanced Clustering Algorithm, improves the communication among dissimilar sensors in the network. To analyze the effectiveness of the technique, the performance of WSNs spread over numerous dissimilar routing procedures are considered.

2. Energy Efficient Cluster Head Selection

Most of the existing clustering algorithms use only one metric: Power, lower-id, highest degree, mobility, node connectivity to elect cluster head. Weight based cluster algorithms use combination of degree; mobility; number of members and node stability. None of the algorithms use the combination of important metrics. In ECSHA[13], CH is selected based on the number of neighbors, residual energy and distance of a node from the middle of the cluster. CH selection is restricted to nodes near the centre of the cluster only. It affects the performance of the network. Hence we have proposed an algorithm to elect a CH in WSNS based on the parameters Residual Energy (E_{res}), Connection Density (CD), Capability of the node (Cn) and Degree of the node (D). The following assumptions are made in this proposed work.

- The position of sensor nodes and BS are fixed.
- The links are symmetric.
- The nodes are randomly distributed.
- All the sensor nodes sense the environment and they have the data to send to BS.
- Distance between two nodes is computed based on Received Signal Strength Indicator (RSSI).

The network is represented by the graph $G(V, E)$ where V is the set of sensors and E is the set of edges. The flow chart for EECHDC scheme is shown in Figure 1. The algorithm for CH selection can be broken down into the following:

2.1 Setup Phase

In this phase, BS broadcasts a message to the sensor nodes. The sensor nodes that receive the broadcast message will leave a reply message which includes the position of the node, node's ID and the distance between the nodes.

2.2 Cluster Head Selection Phase

In CH selection phase, all the sensor nodes will keep their receivers on. The CHs are selected from all the sensor nodes present inside the communication network. The CH selection is based on residual energy, connection density, capability of the node and the degree of the node.

2.2.1 Residual Energy

The energy remaining in a node at the current instance of time is called as residual energy (E_{res}). For a node to become

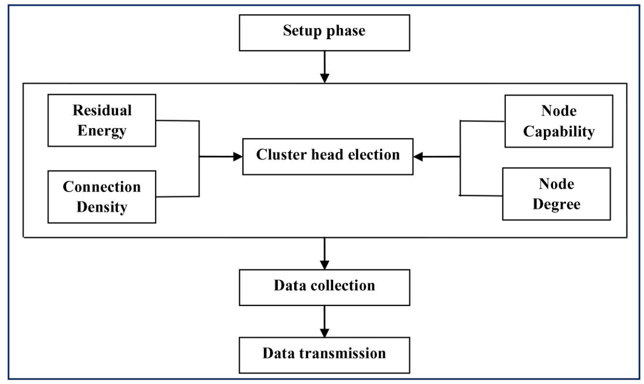

Figure 1. EECHDC strategy.

a CH it should have more residual energy compared to its neighboring nodes. Consider E_i be the initial energy of the node. The energy consumed by the node $(E(t))$ after t time period is given by the Equation (1).

$$E(t) = (n_{tpkts} * \alpha) + (n_{rpkts} * \beta) \quad (1)$$

where

n_{tpkts} = Number of data packets transmitted.
n_{rpkts} = Number of data packets received.
α, β = Constants in the range (0,1).

The E_{res} of a node at time t is computed using the Equation (2).

$$E_{res} = E_i - E(t) \quad (2)$$

2.2.2 Connection Density

Connection Density (CD(x)) of the node is calculated from ratio of average distance from other nodes in same cluster and inter-node distance. Connection density is given in Equation (3).

$$CD(\mathrm{x}) = \sum_{1}^{N(x)} [(x, y) \in E / y \in N(x)] / |N(x)| \quad (3)$$

where
$|N(x)|$ = Number of neighbors of node x.
Y = node

2.2.3 Capability of the Node

The ability of the node to become a CH from a group of sensor nodes is termed as the capability of the node. A large value of capability indicates more ability of a node to become a CH. If capability>Threshold (T) % (1 to 100), then the node becomes a challenger node for being a CH. The threshold value must be selected such that it guarantees enough challenger nodes for quality CH selection.

2.2.4 Degree of the Node

The degree of the node x denoted by $d(x)$ is the number of neighbors of node$x$ (i.e.) the number of links. CH is selected based on the node with maximum number of neighbors. A node of $d(x) = 0$ is isolated (no neighbors). The degree of graph G is denoted in Equation (4).

$$d(G) = \{d(x)\} \quad (4)$$

2.3 Data Collection Phase

Once the CH is selected and is known to all the cluster members, the cluster members send the data packets to their CHs. On receiving the data packets from the cluster members, the CH performs data aggregation.

2.4 Data Transmission Phase

In data transmission phase, the aggregated data packets are relayed to BS through several CHs if the sink is not in communication range or directly to sink if the sink is within the communication range.

3. Performance Evaluation

The performance of the proposed scheme is analyzed by using NS2. NS2 is a discrete event time driven simulator which is used to mainly model the protocols in the network. The nodes are distributed in the simulation environment. The parameters used for the simulation of the proposed scheme are tabulated in Table 1.

The simulation of the proposed scheme has 50 nodes deployed in the simulation area 900 × 900. The nodes communicate with each other by using the communication protocol User Datagram Protocol (UDP). The traffic is handled using the traffic model CBR. The radio waves are propagated by using the propagation model two ray ground. The performance of the EECHDC scheme is evaluated by the parameters packet delivery rate, packet loss rate, average delay, throughput, residual energy and network lifetime.

Table 1. Simulation parameters

Parameter	Value
Channel Type	Wireless Channel
Simulation Time	100 ms
Number of nodes	50
MAC type	802.11
Traffic model	CBR
Simulation Area	900 × 900
Transmission range	250 m
Network interface Type	Wireless Phy

3.1 Packet Delivery Rate

The Packet Delivery Rate (PDR) is the rate of number of packets delivered to all receivers to the number of data packets sent by the source node. The PDR is calculated by Equation (5).

$$PDR = \frac{\sum_0^n Packets\ Received}{\sum_0^n Packets\ Sent} \quad (5)$$

From Figure 2, the PDR of the proposed schemeis increased by 18% compared to the existing scheme ECSHA. This is because of the QoS improved during the estimation of the connection density and residual energy parameters in the route selection process of the method proposed. The greater value of PDR means good performance of the network protocol.

3.2 Packet Loss Rate

The Packet Loss Rate (PLR) is the rate of the number of packets dropped to the number of data packets sent. The formula used to calculate the PLR is calculated in Equation (6).

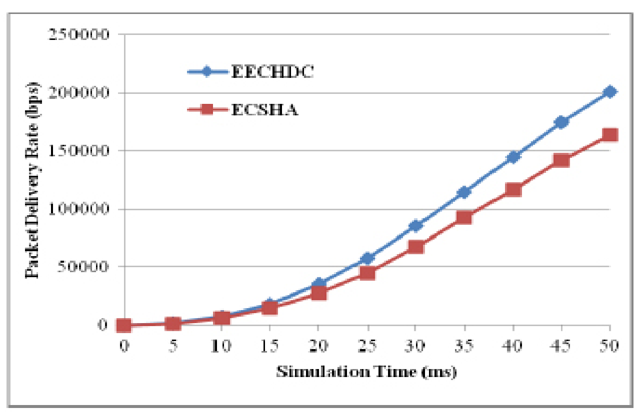

Figure 2. Packet delivery rate.

$$PLR = \frac{\sum_0^n Packets\ Dropped}{\sum_0^n Packets\ Sent} \quad (6)$$

The PLR of the EECHDC scheme is lower by more than 11% compared to the existing ECSHA in Figure 3. Lower the PLR, higher the performance of the network.

3.3 Average Delay

The average delay is defined as the time difference between the previous packet received and the current packet sent. It is measured by Equation (7).

$$Average\ Delay = \frac{1}{n}\left(\sum_0^n Pkt\ Recvd\ Time - Pkt\ Sent\ Time\right) \quad (7)$$

Figure 4 shows that the average delay is low by more than 23% for the proposed scheme RVSPR than the existing ECSHA. The minimum value of delay means higher value of the throughput in the network. This graph justifies the fact that the hindrances in the communication are lesser among the nodes in the network, which shows a significant average delay.

3.4 Throughput

Throughput is the average of successful messages delivered to the destination. The average throughput is estimated using Equation (8).

$$Throughput = \frac{\sum_0^n PktsReceived(n) * PktSize}{1000} \quad (8)$$

Figure 5 shows that the EECHDC scheme has more than 18% throughput compared to the existing scheme ECSHA. Since there is increase in packet delivery ratio, the throughput is automatically increased.

3.5 Residual Energy

The amount of energy residual in a node at the present instance of time is called as residual energy. The energy efficiency is shown in the Figure 6.

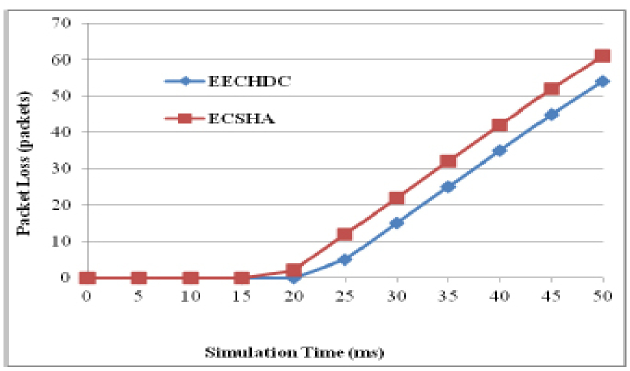

Figure 3. Packet loss rate.

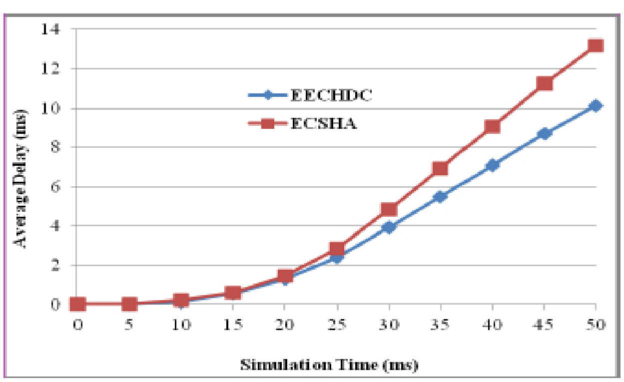

Figure 4. Average delay.

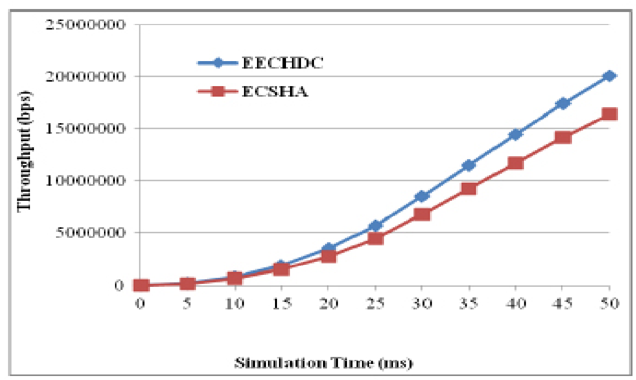

Figure 5. Throughput.

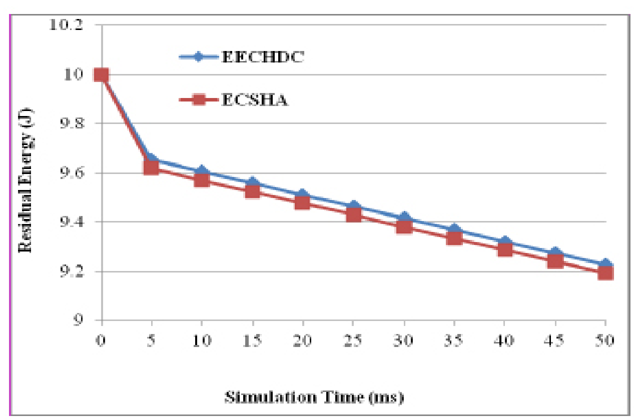

Figure 6. Residual energy.

Figure 6 shows that the residual energy of the network is better for the EECHDC scheme when compared with the existing ECSHA.

4. Conclusion

Lots of research are going on in energy efficiency which is an important issue in WSN. Cluster Head (CH) selection plays a vital role in clustering based techniques. In this paper, an Energy Efficient Cluster Head selection scheme for Data Convening (EECHDC) in WSNs is proposed. CH selection is based on residual energy, connection density, capability of the node and degree of the node. Simulation results show that the EECHDC algorithm achieve higher energy efficiency compared to the ECSHA scheme.

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