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# A Review on Energy-Balanced Routing Method for Wireless Sensor Network

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**Abstract**— Wireless sensor networks are an emerging technology for monitoring physical world. The energy constraint of Wireless sensor networks makes energy saving and Prolonging the network lifetime become the most important goals of various routing protocols. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption. Also putting few nodes in wireless sensor network is an effective way to increase the network lifetime and stability. The energy saving schemes for homogeneous wireless sensor networks do not perform efficiently when applied to heterogeneous wireless sensor networks. Thus, Energy efficient clustering protocols should be designed for the characteristic of each wireless sensor networks. This paper surveys different energy efficient clustering protocols for wireless sensor networks.

**Keywords**— wireless sensor network, clustering protocol, energy efficient, heterogeneous. Energy balance, forward-aware factor, industrial application (IA), routing.

## INTRODUCTION

A collection of mobile or static nodes which are able to communicate with each other for transferring data more efficiently and autonomously can be defined as wireless sensor network. A lot of applications of wireless sensor network can be found in different field such as events, battlefield surveillance, recognition security, drug identification and automatic security [1].

In wireless sensor network, one of the main constraints is limited battery power which plays a great influence on the lifetime and the quality of the network. Several routing protocols have been designed for wireless sensor networks to satisfy energy utilization and efficiency requirement. Efficiency, scalability and lifetime of wireless sensor network can be enhanced using hierarchical routing. Here, sensors are organized themselves into clusters and each cluster has a cluster head [1].The main role of cluster head is to provide data communication between sensor nodes and the base station efficiently[2].

Another way to prolong the lifetime of wireless sensor network is to insert a percentage of heterogeneous nodes. Wireless sensor network consists of sensor nodes with different ability, such as different computing power and sensing range. Heterogeneous wireless sensor networks are very much useful in real deployments because they are more close to real life situations [3, 4].

There are two types of clustering techniques. The clustering technique applied in homogeneous sensor networks is called homogeneous clustering schemes, and the clustering technique applied in the heterogeneous sensor networks is referred to as heterogeneous clustering schemes. Many existing clustering techniques such as LEACH consider homogeneous sensor networks where all sensor nodes are designed with the same battery energy. Thus, Energy efficient clustering protocols should be designed for the characteristic of heterogeneous wireless sensor networks [3].

In this paper, we provide a complete survey of different energy efficient clustering protocols for wireless sensor networks.

## 2.ROUTING PROTOCOLS

### *A. ENERGY EFFICIENT CLUSTERING PROTOCOLS*

Katiyar et al. [4] surveyed clustering algorithms for wireless sensor networks. They classified clustering algorithms based on two main criterions: according to the stability and energy efficiency. They also surveyed several energy-efficient clustering protocols for heterogeneous wireless sensor networks. In this section, we want to survey and compare other energy efficient protocols for clustering in wireless sensor networks.

### *B. ENERGY EFFICIENT HETEROGENEOUS CLUSTERED SCHEME*

Dilipand and Patel [5] proposed an energy efficient heterogeneous clustered scheme (EEHC), for electing cluster heads in a distributed fashion in hierarchical wireless sensor networks. The election probabilities of cluster heads are weighted by the residual energy of a node relative to that of other nodes in the network. The algorithm is based on LEACH and works on the election processes of the cluster head in presence of heterogeneity of nodes. Simulations results show that EEHC is more effective in prolonging the network lifetime compared with LEACH.

*C. DISTRIBUTED ENERGY BALANCE CLUSTERING PROTOCOL*

Changmin Duan and Hong Fan [7] proposed a distributed energy balance clustering (DEBC) protocol for wireless sensor networks. Cluster heads are selected by a probability depending on the ratio between remaining energy of node and the average energy of network. The high initial and remaining energy nodes have more chances to be the cluster heads than the low energy nodes. This protocol also considers two-level heterogeneity and then it extends the results for multi-level heterogeneity. DEBC is different from LEACH, which make sure each node can be cluster head in each ni=1/p rounds. Simulation results show that the performance of DEBC is better than LEACH and SEP.

*D. WEIGHTED ELECTION PROTOCOL*

Rashed et al. [1] proposed an energy-efficient routing protocol in order to enhance the stability period of wireless sensor networks. This protocol is called weighted election protocol (WEP). It introduces a scheme to combine clustering strategy with chain routing algorithm for satisfy both energy and stable period constrains under heterogeneous environment in wireless sensor networks. In the scheme, the authors have considered the following assumptions:

- Each sensor node has power control and the ability to transmit data to any other sensor node or directly to the base station.
- In the model, two types of nodes are used such as advanced node and normal node where advanced nodes have more energy than normal ones.
- Advanced nodes have to become cluster heads more often than that of normal nodes by separate threshold for each type of nodes.
- There is no mobility.

WEP assigns a weight to the optimal probability popt for each node. This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. After assigning weighted probability of each type nodes, this protocol can elect cluster head and their associated non-cluster head as the same way as it done in LEACH protocol. Then that can use greedy algorithm to make a chain among the selected cluster heads. After constructing chain among cluster head nodes, a chain leader is selected randomly. Using TDMA schedule, all non-cluster head nodes send their data to their respective cluster head nodes. The cluster head nodes in each cluster then fused those data and finally send to the base station. Simulation results show that WEP performs better than LEACH, SEP and HEARP in terms of stability period and network lifetime.

*E. DISTRIBUTED ENERGY EFFICIENT CLUSTERING ALGORITHM*

Qing et al [8] proposed a distributed energy efficient clustering scheme for wireless sensor networks, which is called DEEC. In DEEC, the cluster heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster heads for nodes are different according to their initial and residual energy.

The authors have assumed that all the nodes of the sensor network are equipped with different amount of energy, which is a source of heterogeneity. DEEC is also based on LEACH; it rotates the cluster head role among all nodes to expend energy uniformity.

Two levels of nodes are considered in the algorithm and after that a general solution for multi-level heterogeneity is obtained. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is used to compute the reference energy that each node should expend during a round. Simulation results show that DEEC achieves longer lifetime and more effective messages than LEACH, SEP and LEACH-E.

*F. DEVELOPED DISTRIBUTED ENERGY-EFFICIENT CLUSTERING (DDEEC)*

Elbhiri et al. [9] proposed a developed distributed energy efficient clustering scheme for wireless sensor networks. This technique is based on changing dynamically and with more efficiency the cluster head election probability.

DDEEC is based on DEEC scheme, where all nodes use the initial and residual energy level to define the cluster heads. To evade that each node needs to have the global knowledge of the networks, DDEEC like DEEC estimate the ideal value of network lifetime, which is used to compute the reference energy that each node should expend during each round.

In the scheme, the network is organized into a clustering hierarchy, and the cluster heads collect measurements information from cluster nodes and transmit the aggregated data to the base station directly. Moreover, The authors have supposed that the network topology is fixed and no-varying on time. The difference between DDEEC and DEEC is localized in the expression which defines the probability to be a cluster head for normal and advanced nodes. Simulation results show that the protocol performs better than the SEP and DEEC in terms of network lifetime and first node dies.

*G. STOCHASTIC DISTRIBUTED ENERGY EFFICIENT CLUSTERING (SDEEC)*

An improvement of DEEC is proposed as stochastic DEEC by Elbhiri et al. [10]. SDEEC is a self-organized network with dynamic clustering concept. This protocol introduces a dynamic method where the cluster head selection probability is more efficient. In this protocol, The cluster head selection in overall network is based on nodes' residual energy.

According to the protocol, all non-cluster head nodes send data to respective cluster heads in their allocated transmission time. The cluster head node must keep its receiver on, in order to receive all the data from the nodes in the cluster. Some signal processing is performed by cluster head to compress the data into a single signal when all the data is received. After this phase, each cluster head sends the aggregated data to its prime cluster head. Each non-cluster head can turn off to the sleep mode to conserve the energy. The drawback in the protocol is that if non-cluster head nodes turn off to the sleep mode when cluster head is performing aggregation, how they will come to know about the next round of cluster head selection. Simulation results show that SDEEC performs better than SEP and DEEC in terms of network lifetime.

*H. THRESHOLD DISTRIBUTED ENERGY EFFICIENT CLUSTERING PROTOCOL*

Saini and K. Sharma [2] proposed an energy efficient cluster head scheme for wireless sensor networks, which is called TDEEC (Threshold Distributed Energy Efficient Clustering) protocol.

In the scheme, the authors have considered the following assumptions:

- Sensor nodes are uniformly randomly deployed in the network.
- Nodes are location-unaware, i.e. not equipped with GPS capable antennae.
- Nodes have similar processing and communication capabilities and equal significance.
- Sensor nodes have heterogeneity in terms of energy i.e., different energy levels. All nodes have different initial energy; some nodes are equipped with more energy than the normal nodes.

*I. CLUSTER-BASED SERVICE DISCOVERY*

Marin et al. [11] proposed an energy efficient service discovery protocol (C4SD) for wireless sensor networks. The protocol relies on a clustering structure that offers distributed storage of service descriptions. In the protocol, each node is assigned a unique hardware identifier and weight (capability grade). Higher the capability grade more suitability for cluster head role. These nodes act as a distributed directory of service registrations for the nodes in the cluster. The structure ensures low construction and maintenance overhead, reacts rapidly to topological changes of the sensor network by making decisions based only on the 1-hop neighborhood information and avoids the chain-reaction problems. A service lookup results in visiting only the directory nodes, which ensures a low discovery cost. Simulation results show that C4SD performs better than DMAC (Distributed Mobility Adaptive Clustering).

*J. IMPROVED AND BALANCED LEACH*

Said et al. [12] proposed an improved and balanced LEACH which is called IB-LEACH. IB-LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In the scheme, some high energy nodes called NCG nodes (normal node/cluster head/gateway) become cluster heads to aggregate the data of their cluster members and transmit it to the chosen gateways that requires the minimum communication energy to reduce the energy consumption of cluster head and decrease probability of failure nodes.

Working of IB-LEACH is as follows: Sensor nodes elect themselves to be gateway at any given time with a certain probability. Base station confirms that whether those nodes suit to be gateway. These nodes broadcast their status to the other sensors in the network using advertisement message (ADV). The non-gateway nodes elect themselves to be cluster heads with a certain probability. These cluster head nodes broadcast their status to the other sensors in the network using advertisement message (ADV). The non-cluster head nodes wait the cluster head announcement from other nodes. Each sensor node determines to which cluster it wants to belong by choosing the cluster head that requires the minimum communication energy, and send the join-request (Join-REQ) message to the chosen cluster head, and the cluster head nodes wait for join-request message from other nodes.

Once all the nodes are organized into clusters, each cluster head creates a schedule for the nodes in its cluster. This allows the radio components of each non-cluster head node to be turned off at all times except for its transmit time, thus minimizing the energy dissipated in the individual sensors.

*K. DISTRIBUTED CLUSTER HEAD ELECTION (DCHE) SCHEME*

Kumar et al. [3] proposed a distributed cluster head election scheme for heterogeneous sensor networks. The election of cluster heads is based on different weighted probability. The cluster's member nodes communicate with the elected cluster head and then cluster heads communicate the aggregated information to the base station via single-hop communication. The authors have considered three types of nodes where type-3 and type-2 nodes are equipped with more battery energy than type-1 node. All the nodes are uniformly distributed over the field and they are not mobile. Simulation results show that the DCHE scheme offers a much better performance in terms of lifetime and stability than LEACH, DEEC and Direct Transmission (DT).

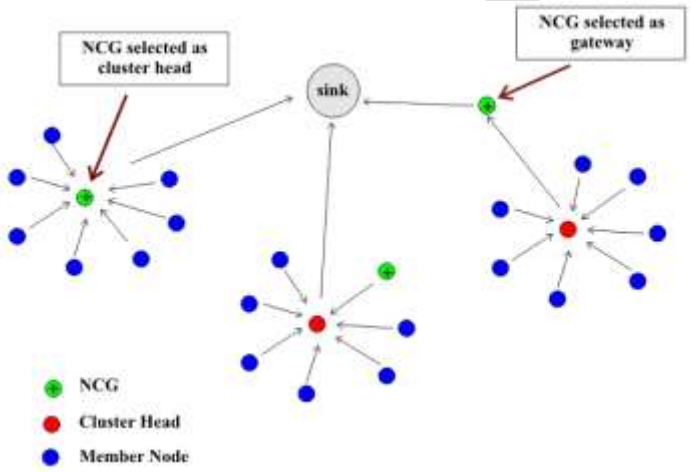


Fig 1. IB-LEACH Network Model [12]

*L. HETEROGENEOUS-HYBRID ENERGY EFFICIENT DISTRIBUTED PROTOCOL*

Kour and Sharma [13] proposed a Heterogeneous-hybrid energy efficient distributed protocol (H-HEED) for Wireless Sensor Network to prolong the network lifetime. The authors have assumed that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network which creates heterogeneity in terms of node energy.

Cluster head selection is primarily based on the residual energy of each node. The authors introduced different level of heterogeneity: 2-level, 3-level and multi-level in terms of the node energy. Simulation results demonstrate that H-HEED achieves longer lifetime and more effective data packets in comparison with the HEED protocol.

*M. CLUSTER BASED ENERGY BALANCING SCHEME*

Jing et al. [14] proposed a novel cluster based energy balancing scheme. They have assumed the existence of a fraction of "strong" nodes in terms of abundant storage, computing and communication abilities as well as energy. The strong nodes act as cluster heads to gather information from the sensor nodes within the cluster via multi-hop link and then communicate with the sink directly via single-hop link.

In the scheme, the cluster heads should be able to form a connected backbone between themselves such that they can communicate without relying on regular nodes. Two types of communication are assumed: one between the regular nodes and the cluster heads with low transmission power, and the communication between cluster heads with higher transmission range spawning larger distances. In a practical deployment, these two types of traffic may be carried on different frequency bands or encoding techniques.

The clustering scheme reduces the depth of the average multi-hop path to the cluster head and transforms the single heavy "hot spot" around the sink to various distributed lighter "hot spots" around corresponding cluster heads. The ratio of the strong nodes to regular nodes determines the average depth of the multi-hop path inside the cluster. The essence of the scheme explores the tradeoff between the multi-hop communication within the clusters and single-hop communication among clusters to achieve a better utilization of the energy resources.

*N. CLUSTER HEAD RELAY ROUTING PROTOCOL*

Du and Lin [15] proposed a cluster head relay (CHR) routing protocol for heterogeneous sensor networks. This protocol uses two types of sensors to form a heterogeneous network with a single sink: a large number of low-end sensors, denoted by L-sensors, and a small number of powerful high-end sensors, denoted by H-sensors. Both types of sensors are static and aware of their locations using some location service. Moreover, both L-sensor and H-sensors are uniformly and randomly distributed in the sensor field. The CHR protocol partitions the heterogeneous network into clusters, each being composed of L-sensors and led by an H-sensor. Within a cluster, the L-sensors are in charge of sensing the underlying environment and forwarding data packets originated by other L-sensors toward their cluster head in a multi-hop fashion. The H-sensors, on the other hand, are responsible for data fusion within their own clusters and forwarding aggregated data packets originated from other cluster heads toward the sink in a multi-hop fashion using only cluster heads. While L-sensors use short-range data transmission to their neighboring H-sensors within the same cluster, H-sensors perform long-range data communication to other neighboring H-sensors and the sink. Simulation results demonstrate that CHR performs better than directed diffusion and SWR.

*O. ENERGY EFFICIENT CLUSTER HEAD ELECTION PROTOCOL*

LI Han proposed [16] an energy efficient cluster head election protocol for heterogeneous wireless sensor networks and using the improved Prim's algorithm to construct an inter cluster routing. He has considered three types of sensor nodes. Some fraction of the sensor nodes are equipped with the additional energy resources than the other nodes. He has assumed that all the sensor nodes are uniformly distributed.

In the protocol, the cluster head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This ensures that there are no collisions among data messages and also allows the radio components of each non-cluster head node to be turned off at all times except during their transmit time, thus minimizing the energy dissipated by the individual sensors.

In order to reduce the energy consumption of the cluster heads which are far away from the base station and balance the energy consumption of the cluster heads which are close to the base station, a multiple-hop routing algorithm of cluster head has been presented, which introduces into the restriction factor of remainder energy when selects the interim nodes between cluster heads and base station, and also the minimum spanning tree algorithm has been included. The protocol can not only reduce the consumption of transmit energy of cluster head, but also the consumption of communication energy between non-cluster head and cluster head nodes. Simulation results show that this protocol performs better than LEACH and EECHE in terms of network lifetime.

*P. CLUSTER MULTI-HOP TRANSMISSION (CMHT )*

Xuegong et al. [17] proposed a new protocol of the Cluster Multi-Hop Transmission (CMHT) for sensor networks. The algorithm selects cluster head nodes by calculating weight-value and transfers data by using nodes in cluster and cluster-head multi-hop transmission manner.

CMHT protocol has advantages such as following:

- Improving the method of election of cluster head and introducing the concept of weighting factor, so each node can determine their own probability of being cluster head in accordance with its own situation. Through dynamic adjustment of proportion of three parameters of the ratio of energy consumption, the remaining energy and the average of energy consumption, location and the numbers of being cluster head, optimize the cluster.
- Balancing the energy consumption, reducing the phenomenon of rapid death of the cluster head caused by excessive energy consumption, also preventing the situation of cluster chain block caused by one cluster head failure to work, ensure that the cluster chain work normally.
- Through extending the stable phase of data communication time, it extends the time of each cycle, thereby reducing number of cyclical re-establishment of cluster. Then it reduces the frequency of cluster head election, so saves a large number of energy cost of the frequent cluster head election and prolonging the survival time of the network.
- Using cluster and cluster head multi-hop transmission manner, it saves excessive energy consumption for long-distance transmission, increased energy utilization of the entire network.

The simulation results show that this protocol could suitably form clusters and effectively prolonging the survival time of the entire networks.

*Q. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH) PROTOCOL*

LEACH protocol is one of the most famous WSN hierarchical

routing algorithms. In LEACH, the nodes organize themselves

into local cluster, the protocol is divided into a setup phase when the clusters are organized and a steady-state phase when data are transferred from the nodes to the cluster head and on to the sink [18]–[19]. In the setup phase, each node choose a random number between 0 and 1, if this number is less than a certain threshold T(n), the node will broadcast itself as the cluster head. The non cluster head node chooses the cluster head with greater signal strength and join the cluster, and then the cluster head node receives data from all of the cluster members and transmits data to the remote sink [20]–[23].

In the steady-state phase, data are transferred from the nodes to the cluster head and on to the sink. After each round, a new cluster head will be chosen, and in this way the energy load of being a cluster head is evenly distributed among the nodes.

*R. ENERGY-EFFICIENT UNEVEN CLUSTERING (EEUC) PROTOCOL*

EEUC is an uneven clustering routing protocol in which tentative cluster heads use uneven competition ranges to construct clusters of uneven sizes [24]–[27].It shows that the clusters closer to the sink have smaller sizes than those farther away from the sink, thus the cluster heads closer to the sink can preserve some energy for the inter-cluster data forwarding.

*S. BALANCED ROUTING METHOD BASED ON FORWARD AWARE FACTOR*

Degang shang et al. have done based on the detailed analysis of the data transmission mechanism of WSN, they quantify the forward transmission area, define forward energy density, which constitutes forward-aware factor with link weight, and propose a new energy-balance routing protocol based on forward-aware factor, thus balancing the energy consumption and prolonging the function lifetime.

**CONCLUSION**

Wireless sensor networks are not always homogeneous, they may be heterogeneous too. The life time and reliability of the network can be improved by heterogeneity in wireless sensor networks. Clustering is a good technique to reduce energy consumption and to provide stability in wireless sensor networks. To operate under wireless sensor networks, several protocols are proposed. Most of the recent energy efficient protocols designed for networks are based on the clustering technique, which are effective in energy saving for wireless sensor networks. In this paper, we surveyed energy efficient clustering protocols in wireless sensor networks and compared these protocols based on clustering attributes. Studies of the performance of the clustering algorithms in saving energy for heterogeneous wireless sensor networks, showed that energy efficient clustering protocols for heterogeneous wireless sensor network, have better performance than energy efficient clustering protocols for homogeneous wireless sensor network in prolonging the network lifetime.

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