

Inheritors of LEACH for Heterogeneous Wireless Sensor Networks

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Abstract

Efficient energy management is a key challenge in Wireless Sensor Network (WSN) to prolong the network lifetime. Many researchers are given energy efficient solution for homogeneous and heterogeneous WSNs. From literature, it is shown that addition of heterogeneity in the network augments reliability and lifespan of the network. LEACH is a clustering algorithm initially designed for homogeneous WSNs. There exist many inheritors of LEACH designed for homogeneous or heterogeneous networks. This paper presents a survey on heterogeneous inheritors of LEACH.

1. INTRODUCTION

Wireless sensor networks consist of numerous minute low-cost nodes are deployed in sensor field to sense information from the surrounding and forward it to a base station or sink [1]. Sensor nodes are deployed in the sensor field randomly, uniformly or in a pre-planned manner [2]. Each sensor node has restricted battery. These batteries cannot be recharged or replaced when deployed in an unattended or hostile sensor field [3]. The life of a sensor node depends upon its battery lifetime. It is essential to efficiently utilize their energy so that they may survive for longer period to keep network functional [4]. Therefore, extending the network survivability by efficiently utilizing network energy is the key design challenge for WSN.

From literature, it is observed that clustering in routing data is an efficient approach to preserve network energy and prolong network survivability [5]. LEACH (Low Energy Adaptive Clustering Hierarchy) is the pioneer model for clustering routing techniques proposed in year 2000 [6]. It is designed with an aim to balance energy consumption amongst all nodes in order to prolong network survivability. The algorithm ruptures all the live nodes into clusters and one node is chosen as Cluster Head (CH) of the cluster. CH is responsible to collect information from the member nodes of the cluster, aggregate the collected data with its own data and forwards it to the sink. The role of CH is rotated randomly among all live node to balance the energy load. Many researchers have proposed modified versions of LEACH (called inheritors of LEACH) for homogeneous or heterogeneous WSNs to overcome the limitation of LEACH [5]. From the literature, it is found that added heterogeneity in the network enhances its reliability and survivability. This paper provides an overview for the inheritors of LEACH for heterogeneous WSNs.

2. INHERITORS OF LEACH FOR HETEROGENOUS WSNs

WSNs can either be homogeneous or heterogeneous networks. In heterogeneous networks, the nodes have different initial battery power. When a sensor network starts its network operation, even after first round all nodes may have different battery power levels. In order to implement the concept, researchers considered different types of nodes depending upon the initial energies assigned to them. There are many protocols found in the literature which are heterogeneity aware and enhanced versions of LEACH. These algorithms are categorised as single-hop and multi-hop routing algorithms depending upon the maximum number of hops required to transmit data from a CH node to the sink. In this section an effort has been made to survey deeply the heterogeneous aware protocols.

2.1. Single Hop LEACH variants

In single hop algorithms, all the CH nodes directly transmitting data to the sink. The single-hop LEACH variants are described as under:

SEP (Stable Election Protocol) introduced a modified cluster head selection method with an aim to increase the stability period of the network. A weighted election probability function for each node to become a CH is proposed based upon the initial energy [7].

DEEC (Distributed Energy Efficient Clustering protocol) is a distributive routing algorithm with modified CH method. CH is chosen based upon the current residual energy of node instead of initial energy. The drawback of the technique is that energy consumption amongst all sensor nodes is not balanced [8].

EEHC (Energy Efficient Heterogeneous Clustering) protocol proposed three levels of heterogeneity in WSNs with normal, advanced and super nodes. It takes the advantage of nodes with increased initial energy to enhance the lifetime of the network[9].

DDEEC (Developed DEEC) is a modified DEEC algorithm. Elbhiri et al. have proposed a modified CH selection method to assign probabilities to nodes. The investigators define a transition point during network operation where all nodes in the network have nearly same residual energy, probabilities before the point is assigned according to DEEC and then equal probability is assigned to all nodes to become CH [10].

EDDEEC (Enhanced developed distributed energy-efficient clustering) presented a threshold energy level for changing the probabilities of nodes instead of defining a point network operational time. It is simplified approach as compared to DDEEC [11].

TDEEC(Threshold DEEC) algorithms controls the number of CH elected by modifying the probability function. The parameters considered for probability function are residual energy, average energy of the network and optimum number of cluster heads [12].

SBDEEC (Stochastic and Balanced Distributed Energy- Efficient Clustering) algorithm reduces the number of data transmissions by using stochastic method. Each sensor node transmit the sensed information only when there is significant change in sensed information [13].

BEENISH (Balanced Energy Efficient Network Super Heterogeneous) protocol introduces four level of heterogeneity to implement closer view of real WSN scenarios. The algorithm introduces four types of nodes depending upon their initial energy: normal, advanced, super and ultra-super [14].

Q-DEEC (Quadrature DEEC) divides the network into four quadrants. The sink is placed at the centre of the field. The nodes associated with each quadrant considered as one sub-network and run DEEC. The distribution of CH over the sensor field is more uniform as compared to DEEC. But, it suffers from all other problems of DEEC [15].

2.2. Multi-hop variants of LEACH

All of the techniques discussed in [7-14] use direct transmission from CH to the sink which results into huge wastage of the network energy and overall performance of the network degrades. To overcome the discussed problem, multi-hop routing algorithms are proposed in literature.

EE-TLDC (Energy efficient two level Distributed Clustering) is a distributive clustering protocol and uses two hops routing to send clustered data to the sink. The algorithm considers three level heterogeneous networks and weighted probabilities are assigned to all sensor nodes according to residual energy and average energy of the network. It chooses few secondary CHs (SCHs) from the already selected CHs for the current round [16].

SCBC (Sector-Chain Based Clustering) is a routing protocol which partitions the entire network area into sectors. The algorithm reduces energy dissipation of WSN by constructing chain for each cluster with the chain leader. Leader nodes lying at farther distance transmit data to sink in multi-hop manner [16].

Two-Hop heterogeneity-aware Centralized Energy Efficient Clustering (THCEEC) and Advanced heterogeneity-aware CEEC (ACEEC) introduce three level heterogeneity in the network. These are centralised routing algorithms which initially split the network in provinces which act as static clusters for WSN. The sink finds CH in each cluster and efficient path to route region data to the sink[17].

The contributions made by each algorithms discussed and their limitations are summarised as under:

Table 1: Contributions and Limitations of Heterogeneous Variants of LEACH

Algorithm	Contribution	Limitation
SEP	<ol style="list-style-type: none"> 1. A heterogeneity aware weighted election probability function defined to elect CH. 2. Stable operational period of network is extended. 	<ol style="list-style-type: none"> 1. Advanced nodes have more probability to become CH even at low residual energy. 2. CH dispersion over the sensor field is not uniform. 3. Single hop data transmission to the sink.
DEEC	<ol style="list-style-type: none"> 1. CH is elected based upon the residual 	<ol style="list-style-type: none"> 1. Dispersion of CH is not uniform.

	energy. 2. Stable operational period is extended over SEP.	2. Weightage assigned to advanced nodes are more as compared to normal node.
DDEEC	Probability of a sensor node to become CH is changed and become equal for all nodes when energy levels of all nodes are same.	Calculation of intersection point where residuals energies of all nodes become equal is not optimized.
EDDEEC	1. Three levels of heterogeneity are provided. 2. Unbalanced distribution is avoided by making changes in average probability.	Still the disadvantage of DDEEC and E-DDEEC exist.
TDEEC	Threshold value calculation used to elect CHs is improved by introducing parameters residual energy of node, average energy of network with respect to optimum number of cluster heads. Therefore, the lifetime of network is enhanced.	Other parameters like distance to BS, node density and intra cluster distance which affects the performance of a CH are not considered for its election.
SBDEEC	Data is transmitted only when there is a significant change in sensed information. Otherwise SNs will remain in sleep mode which saves energy consumption in the network.	Use of the protocol is application specific.
EE-TLDC	Stability period is enhanced and hence more reliable	Total Distance covered to transmit data to BS still need to be optimised.
SCBC	Distances are reduced using intra and inter cluster multi-hopping.	The size of cluster is large.
ACEEC	Network is divided into static clusters and adaptive routes are established in each round.	It is a centralised approach and bear large overhead to update status of network in each round.

3. Conclusion

Energy efficiency is a vital issue in WSN to extend network lifetime. Addition of heterogeneity in the network augments reliability and lifespan of the network. Clustering is a prominent solution to reduce network traffic, utilize limited bandwidth and extend network lifetime. LEACH is a role model for clustering algorithms. Various modified versions of LEACH for heterogeneous networks found in the literature are surveyed in this paper. The contributions and limitations of all techniques have also been discussed in the paper.

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