Review on Basic Clustering Techniques for Heterogeneous Wireless Sensor Networks

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Abstract- Clustering technique is the basic technique used in the wireless sensor network to enhance the lifetime of a sensor network by mitigating energy consumption and provide efficiency, scalability, and security. Formerly sensor nodes are considered to be homogeneous in which each node has the same processing capacity, energy and functionality, but to prolong network lifetime researches has been evolved to infuse heterogeneity in wireless sensor network such as to provide different energy level to some nodes. In this paper, we present a survey on basic clustering techniques for Heterogeneous wireless sensor networks.

Index Terms- Wireless Sensor Network (WSN), Clustering, Heterogeneous, Cluster Head (CH), Sensor Node (SN). I.

I. INTRODUCTION

Wireless sensor network is a collection of tiny, resource constrained sensors interconnected with each other to gather data about physical or environmental objects [1]. Data gathered by sensors is propagated towards a gateway (base station) that connects the network with wired or other type of networks where data can be analyzed to generate the results [1] [2]. In the small sensor networks, nodes are directly connected to base station, that is, single hop communication between nodes and the base station may be feasible. In the case of large WSN which cover a large geographical area, direct coverage between all the nodes and the base station is not possible. In such large network multihop communication takes place. For communication, SNs produce and disseminates information and works as relays. The process of sending a data from source node to its ultimate destination through one or more forwarding node is called routing. It is the main responsibility of the network layer is to send data from one node to another in WSN.

Due to limited resource constrained like limited computation power, energy, storage, bandwidth and dynamic changes in topology, WSN is unable to provide efficiency in transmission, and network lifetime. These days, clustering techniques is extensively applied as one of the solutions to confront with this limitation. In this paper, we primarily focus on Clustering protocols for WSNs.

Clustering technique is the basic technique used in the wireless sensor network to enhance the lifetime of a sensor network by mitigating energy consumption [3] and provide efficiency, scalability, security. Clustering is a process of dividing WSN into small networks of tiny sensor nodes. These small networks known as clusters and each cluster is under the administration of special sensor node often referred to as a Cluster Head(CH). In each cluster, CH may be elected by the sensor nodes or pre-defined by the network administrator. The Cluster contains two kind of nodes one is CH and other one is Sensor Node (SN). SNs are low energy nodes as compared to CHs, higher energy nodes (CH) perform the all kinds of processing and routing of information [4] while low energy SNs can be used to perform only sensing task. The CH can prolong the battery life of the individual sensors and the network lifetime as well by implementing optimized management strategies [4][5]. Various clustering [7] [8] techniques have been particularly designed for WSNs for scalable and efficient communication. The concept of cluster based routing is also utilized to perform energy-efficient routing in WSNs.

II. CLUSTERING ATTRIBUTES

In this section we present the set of attributes that can be used to classify and segregate the clustering algorithm of HWSNs. According to the attributes described in [9], we also present here some attributes which are described below:

(A) Cluster Competency:

We can define two types of cluster attributes to separate the clustering algorithms.

- Intra-cluster Topology: Many clustering Techniques are based on single-hop communication between a sensor and its designated CH, but sometimes multi-hop Communication is required.
- CH to BS link: BS can communicate only to CHs. CHs send the aggregated information to the BS directly or indirectly with the help of other CH nodes. It means, there exists a direct link or a multi-hop link.

(B) Cluster-Head Competency:

We can differentiate the clustering algorithms according to the attributes of CH node.

- Mobility: Generally CHs are stationary nodes, but in some cases it can be mobile to reposition themselves to improve coverage and network performance.
- Kind of nodes: some sensor nodes consist of more processing power, computational capability, and energy. These kinds of nodes are generally elected as CHs.
- Task: major task of CH is to aggregate and infuse the collected information and send it towards the base-station.

(C) Selection of CH:

- Initial Energy: CH selection mechanism starts with the initial energy of the nodes. Every algorithm considers initial energy.
- Residual Energy: After some processing in WSN, CH election should be based on the remaining energy of sensor nodes.
- Average Energy of the Network: The average energy is used as the reference energy for each node. It is the ideal energy that each node should own in the current round to keep the network alive.

III. CLUSTERING ALGORITHMS FOR HWSNS

Clustering is an efficient mechanism to prolong the WSN lifetime by reducing the energy consumption and improves stability. In HWSNs, clustering algorithm should be energy efficient. We present the clustering algorithms in this paper based on energy efficiency and stability.

(A) Stability-based protocols for clustering in HWSNs.
Stability-based clustering protocols enhance the stability period of WSNs. Stability period is defined as the time interval before the death of the first node. The protocols come in this category are discussed below:

(i) Stable Election Protocol:
Smaragdakis G. et al. [9] Illustrate the effect of heterogeneity on WSNs and also describe the instability of some protocols, in the presence of heterogeneity, once some nodes die. Author describes some issues that occur due to heterogeneity of nodes. Stable election protocol is energy aware and does not require the sharing of energy information, but is based on assigning weighted probabilities of each node to be elected as cluster head according to their respective energy. SEP [9] consist of two kinds of nodes, normal and advanced nodes. It is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. This prolongs the stability period, i.e. the time interval before the death of the first node.

(ii) Novel Stable Selection and Reliable Transmission Protocol for Clustered HWSN:
In this paper [10] author proposes a model for HWSN that describes the energy and computational heterogeneity. Author also presents an Energy Dissipation Forecast and Clustering Management (EDFCM) protocol for HWSN. This algorithm will give the prolonged stability period for network and works round by round to balance the energy consumption. In this model, the author proposes three types of nodes that is type_0, type_1 and some management nodes. During the cluster formation, the role of management node is to manage both types of node, While the type_1 and type_2 nodes are responsible for sensing tasks and other functions in terms of energy and software.

(iii) Base Station Initiated Dynamic Routing Protocol:
In [11] authors applied a new routing protocol to prolong the network lifetime used the concept of clustering and nodes heterogeneity. During the cluster head election process, nodes which have largest energy level, computation power and processing capabilities will be elected as CHs. CHs function is to aggregate all the information and send it to the base station. Author considers separate inter-cluster and intra-cluster communication to avoid collision and deployment of sensors are uniform. . In this algorithm, how far a CH is from the base station, is defined as the level. Low level means that CH is near to the BS and if the level is high, it means CH is away from BS accordingly. Data flow will be always from higher level to lower level.

(iv) Routing Protocol for Balancing Energy Consumption in HWSN:
In [12] author proposed a residual energy and energy consumption rate (REECR) protocol, but in terms of balancing the energy REECR was not perfect. To overcome this deficiency, they proposed a zone based REECR protocol named as ZREECR. Balancing the energy is a typical task and it causes instability. To overcome this issue authors proposes [13] ZREECR. This protocol divides the network into fixed-size zones, depending upon distance and orientation from the base station.

(B) Energy-Efficient Clustering Protocol for HWSNs.
The concept of cluster based routing is also utilized to perform energy-efficient routing in WSNs. Efficient organization of sensor nodes into clusters is useful in reducing energy consumption in WSNs.

(i) Energy Efficient Heterogeneous Clustered Scheme:
The authors proposed [13] [14] a novel clustering scheme for HWSN based on the consideration of cluster heads election mechanism in which each node to become cluster head according to weighted election probabilities. It elects the cluster head in a distributed fashion in hierarchal WSN. This algorithm is based on LEACH (Low Energy Adaptive Clustering Hierarchy), the most popular clustering protocol in WSN. In the LEACH algorithm, there is an optimal percentage of nodes that has become a cluster head in each round. This algorithm works on the election processes of the cluster head in the presence of heterogeneity of nodes.

(ii) Distributed Energy-Efficient Clustering Algorithm for HWSN [DEEC]: In [15] authors proposed an algorithm works on the concept of distributed multilevel clustering for heterogeneous wireless sensor networks. Cluster heads selection process in this algorithm is based on the probability in which the ratio of the average energy of the network and nodes residual energy will be considered. How long different nodes would be cluster-heads, is decided according to the initial and residual energy. The authors supposed that all the nodes of the WSN contain different amount of energy, which is a source of heterogeneity. DEEC is LEACH based algorithm thus it expands the life time of network by rotating the role of CH among all nodes. At the start of processing nodes should have kept the prior knowledge of total energy and lifetime of the network. Reference

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energy is also known as the average energy of the network. Thus, DEEC does not require any global knowledge of energy at every election round.

IV. Comparison of Various Existing Clustering Techniques

In aforementioned section, we present various existing clustering algorithms for HWSN based on clustering attributes like clustering competence, cluster head competence, selection of CH. TABLE I reflect the comparison between various clustering techniques for HWSN. Attributes are shown in the table below are the basic parameters, through which all major clustering algorithms are developed.

TABLE I

COMPARISON OF VARIOUS EXISTING CLUSTERING ALGORITHM FOR HWSN.

Clustering Algorithm	Clustering competence		Cluster head Competence			Selection of CH		
	Intra-cluster topology	CH to BS Link	Mobility	Kind of nodes	task	Initial energy	Residual energy	Average energy
SEP	single-hop (Fixed cluster)	Single link (direct connectivity)	stationary	Sensor	aggregation	No	Yes	No
EDFCM	Single hop	Single-link	stationary	Sensor	aggregation	No	Yes	No
BASE-STATION INITIATED	Single hop	Multi-link	stationary	Resource rich	aggregation	Yes	No	No
ZREECR	Single hop	Multi-link	stationary	Sensor	aggregation	No	Yes	No
EEHC	Single hop	Single-link	stationary	Sensor	Relay	No	Yes	No
DEEC	Single hop	Single-link	Micro-Mobile/Stationary	Resource rich	Aggregation/ Relay	No	Yes	Yes

V. CONCLUSION

Clustering is an essential technique to provide stability and decrease consumption of energy. WSN can be heterogeneous also to overcome the deficiency of homogeneous WSN. We classified some crucial protocols according to stability and energy efficiency of network. Finally on the basis of survey work, we conclude that the heterogeneous wireless sensor networks are more suitable for real life applications as compared to the homogeneous counterpart.

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