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A Survey on Energy Efficient Clustering Protocols in Heterogeneous Wireless Sensor Networks

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Abstract: Wireless sensor networks are an emerging technology in recent years and our main challenge is to increase the energy efficiency in wireless sensor network. Clustering is a key technique which will extend the lifetime of a sensor network by reducing energy consumption. We can also increase the network lifetime and stability to design the multilevel heterogeneous model. Homogeneous protocols in wireless sensor networks do not perform efficiently when they applied in heterogeneous wireless sensor networks. Thus, Energy efficient clustering protocols should be designed for heterogeneous wireless sensor networks to increase the reliability. This paper surveys different energy efficient clustering protocols for heterogeneous wireless sensor networks and compares these protocols on various points like, location awareness, clustering method, heterogeneity level and clustering attributes.

Keywords: Cluster Head, heterogeneous, energy efficiency, WSNs.

I. INTRODUCTION

Wireless sensor networks is the network consisting of hundreds of tiny sensor nodes which sense the physical environment in terms of temperature, humidity, light, sound, vibration, etc. These sensor nodes gather the data from the sensing field and send this information to the base station. These sensor nodes can be deployed on many applications like area monitoring, health care monitoring, and industrial monitoring. Current wireless sensor network is working on the problems of low-power communication, sensing, energy storage, and computation. Hierarchical-based routing is a cluster based routing in which advanced energy nodes are randomly selected for processing and sending data while normal energy nodes are used for sensing and send information to the cluster heads. Clustering technique enables the sensor network to work more efficiently. It increases the energy consumption of the sensor network and the lifetime [1].

Clustering is the key technique for decreasing battery consumption in which cluster members which are having high energy and optimal probability become Cluster Head (CH). Many clustering protocols are designed with this approach [2,3]. All the cluster members send their data to CH, where CH aggregates that data and sends that data to Base Station. Under aggregation, fewer messages are sent to BS and some messages which are at far distance from base station sends that message to the nearest cluster head with this energy consumption should decrease. Energy consumption for data aggregation is much less as compared to energy used in data transmission. Clustering are of two types of networks homogenous and heterogeneous networks. Nodes having same energy level are called homogenous network and nodes having different energy levels called heterogeneous network.

Low-Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS) , Hybrid Energy-Efficient Distributed clustering (HEED) [5] are algorithms designed for homogenous WSN and these protocols do not work efficiently in the heterogeneous WSN because these algorithms are unable to treat nodes differently because they have different energy levels. Whereas, Stable Election Protocol (SEP) [4], Distributed Energy-Efficient Clustering (DEEC) [7], Developed DEEC (DDEEC) [9], Enhanced DEEC (EDEEC) [11] and Threshold DEEC (TDEEC) [10] are algorithms designed for heterogeneous WSN. Most of the recent energy efficient protocols designed for heterogeneous networks are based on the clustering technique, which are effective in scalability and energy saving for WSNs. In this paper, we provide a complete literature survey on energy efficient clustering protocols for heterogeneous wireless sensor networks (HWSNs). We can easily summarize that which protocol are more efficient and less energy consumption. Rest of the paper is organized as follows. Section 2 describes the heterogeneous model for wireless sensor networks and Section 3 describes classification of clustering attributes. Sections 4 describe the survey of energy efficient clustering protocols for heterogeneous wireless sensor networks and compare these protocols with other in section 5. Finally, in section 6 conclusion of the paper is presented.

II.HETEROGENEOUS MODEL FOR WIRELESS SENSOR NETWORKS

Type of Resource Heterogeneity

There are three types of resource heterogeneity in sensor nodes computational heterogeneity, link heterogeneity and energy heterogeneity.

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•**Computational heterogeneity** means that the heterogeneous node has a more powerful microprocessor and more memory than the normal node. With powerful computational resources, the heterogeneous nodes can provide complex data processing and longer term storage [2].

•**Link heterogeneity** means that the heterogeneous node has high-bandwidth and long-distance network transceiver than the normal node. Link heterogeneity can provide a more reliable data transmission.

•**Energy heterogeneity** means that the heterogeneous node is line powered or its battery is replaceable. Among above three types of resource heterogeneity, the most important heterogeneity is the energy heterogeneity because both computational heterogeneity and link heterogeneity will consume more energy resource.

Impact of Heterogeneity on Wireless Sensor Networks

Response time: Computational heterogeneity can decrease the processing latency and link heterogeneity can decrease the waiting time, hence response time is decreased.

Lifetime: The average energy consumption of the network in heterogeneous will be less when the data is forwarded from energy nodes to the sink thus lifetime is increased

Performance measures: Some performance measures that are used to evaluate the performance of clustering protocols are as follows:

- **Network lifetime:** It is the time interval from the start of operation of the network to the death of the first alive node.
- **Number of cluster heads per round:** This measure reflects the number of nodes which would directly send to the sink and aggregate information from their cluster members.
- **Number of nodes per round:** This instantaneous measure reflects the total number of nodes that of each type and has not yet consumed all of their energy.

III. CLUSTER PROPERTIES

• **Cluster Count:** CHs are predetermined in some of the published approaches thus; the number of clusters is preset. CH selection algorithms generally pick randomly CHs from the deployed sensors hence yields variable number of clusters.

• **Intra-cluster Topology:** Some clustering schemes are based on direct communication between a sensor and its designated CH, but sometimes multi-hop sensor-to-CH connectivity is required.

• **Connectivity of CH to BS:** CHs send the aggregated data to the BS directly or indirectly with help of other CH nodes. It means, there exists a direct link or a multi-hop link.

•**Initial Energy:** Initially to make the CH initial energy is considered and after that algorithm starts.

•**Residual Energy**: The remaining energy of the network is the residual energy and after some rounds this energy is considered to select the CH [3].

•**Average Energy of the Network**: It is the ideal energy that each node should own in current round to keep the network alive. It is the threshold energy for each node.

IV. ENERGY EFFICIENT CLUSTERING PROTOCOLS FOR HETERGENOUS WIRELESSSENSORNETWORKS

A. Stable Election Protocol for Clustered Heterogeneous Wireless Sensor Networks (SEP)

Georgios S. et al. [4] introduces the heterogeneity that prolongs the time interval before the death of first node called stability period. This protocol is based on the weighted election probabilities of each node to become cluster head according to the remaining energy in each node. In this there are two types of nodes was considered as normal and advanced. This protocol does not require global knowledge of energy at every round to select cluster heads. Authors extended the LEACH protocol except the heterogeneity awareness. Cluster count is variable in this algorithm and also unstable period is not good.

B. Hybrid Energy-Efficient Distributed Clustering Protocol for Heterogeneous Wireless Sensor Networks (HEED)

O. Younis et al. [5] improves the LEACH protocol by using residual energy of the network. This protocol was proposed with three main parameters: First parameter is to enhance network lifetime by distributing energy consumption, second clustering terminates within a fixed number of iterations third minimum control over head and fourth the cluster heads was well distributed. The algorithms proposed in this protocol periodically selects cluster heads based on the two basic parameters. The first primary parameter is the residual energy of each node; second parameter is the intra-cluster communication of the all nodes. The primary parameter selects initial set of cluster heads probabilistically which secondary parameter is breaking ties. HEED is not able to fix the cluster count in each round and it is also not aware of heterogeneity.

C. Distributed Energy Balance Clustering Protocol for Heterogeneous Wireless Sensor Networks (DEBC)

Changmin D et al. [6] proposed a protocol for heterogeneous wireless sensor network. The selection of cluster heads depends on the probability based on radio between residual energy of node to the average energy of network. The high initial and residual energy nodes have more chances to become cluster heads then the nodes have low energy. This protocol improves the LEACH and SEP protocol by considering heterogeneity for two levels and extends up to multihop heterogeneity.

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.

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D. Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Networks (DEEC)

Li Qing et al. [7] proposed a distributed multilevel clustering algorithm for heterogeneous WSN. In DEEC the cluster heads are selected by a probability based on the ratio between residual energy of each node and the average energy of the network. The approach 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. Two levels of heterogeneous 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. Cluster count is variable in this approach lead to uneven clusters. 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. Cluster count is variable in this approach lead to uneven clusters.

E. Stochastic Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Networks (SDEEC)

B. Elbhiri et al. [8] extended the DEEC protocol as the stochastic strategy is the key idea where the number of transmission intra clusters is reduced. This strategy is used when the objective is to collect the maximum or minimum data values like temperature, humidity etc in a region of the network. Thus the cluster head selects pertinent information between those received and send it to the base station. In this case, if the clusters head receives only from nodes with significant information and the others node must be in sleep mode. It is an application specific protocol. Thus the cluster head selects pertinent information between those received and send it to the base station. In this case, if the clusters head receives only from nodes with significant information and the others node must be in sleep mode. It is an application specific protocol.

F. Developed Distributed Energy-Efficient Clustering for Heterogeneous Wireless Sensor Networks (DDEEC)

Elbhri et al. [9] proposed a developed distributed energy efficient clustering scheme for heterogeneous WSNs. DDEEC is based on DEEC scheme, where all nodes use the initial and residual energy level to define the cluster heads. In this protocol 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 this 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.

G. Threshold Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Networks (TDEEC)

ParulSaini et al. [10] proposed an energy efficient cluster head election scheme for heterogeneous WSNs. The author have adjusted the value of the threshold, according to which a node decide to become a cluster head or not, based on the ratio of residual energy and average energy of that round in respect to the optimum number of cluster heads. Two level and three levels of heterogeneous nodes are considered in the algorithm and after that a general solution for multilevel heterogeneity is proposed. It requires the average network energy for cluster head selection, which is more energy consumable.

H. Enhanced Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Networks (EDEEC)

N.Javaid and T.N. Qureshi proposed new protocol Enhanced Distributed Energy Efficient Clustering (EDEEC)[11], for three types of nodes in prolonging the lifetime and stability of the network. Hence, it increases the heterogeneity and energy level of the network. Simulation results show that EDEEC performs better than SEP with more stability and effective messages.

I. Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol (BEENISH)

T. N. Qureshi, N. Javaid proposed BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous) Protocol [12]. It assumes WSN containing four energy levels of nodes. Here, Cluster Heads (CHs) are elected on the bases of residual energy level of nodes. Simulation results show that it performs better than existing clustering protocols in heterogeneous WSNs. Our protocol achieves longer stability, lifetime and more effective messages than Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Enhanced DEEC (EDEEC).

Table 1 Comparison of the Clustering Protocols for Wireless Sensor Networks

Clustering Approach	Energy Efficient	Cluster Stability	Hetero geneity Level	Cluster Head Mobility
SEP	Low	Good	Two	Fixed
HEED	Low	Moderate	Two/ Multi	Fixed
DEBC	Medium	Good	Two/ Multi	Micro Mobile/ Fixed
DEEC	Medium	Moderate	Two/ Multi	Micro Mobile/ Fixed
SDEEC	Medium	Good	Two	Micro Mobile/ Fixed
DDEEC	High	Good	Two/ Multi	Fixed

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TDEEC	High	Good	Two/ Multi	Fixed
EDEEC	High	Good	Three	Fixed
BEENISH	High	Very Good	Four	Fixed

Clustering Approach	Initial Energy	Residual Energy	Average Energy of Network
SEP	**X**	✓	**X**
HEED	**X**	✓	**X**
DEBC	**X**	✓	✓
DEEC	**X**	✓	✓
SDEEC	✓	✓	**X**
DDEEC	✓	✓	**X**
TDEEC	**X**	✓	✓
EDEEC	✓	✓	**X**
BEENISH	✓	✓	**X**

Table 2 Classification based on cluster head capability

V. CONCLUSION

Clustering is a technique to reduce energy consumption and to provide stability in wireless sensor networks. For heterogeneous wireless sensor networks, several clustering protocols are proposed. Most of the recent energy efficient clustering protocols designed for sensor networks are based on residual energy, average energy, location, density etc. which are effective in energy saving. We summarize a number of schemes, stating their strengths and limitations. 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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