Comparison of Energy Efficient Clustering Protocols in Heterogeneous Wireless Sensor Networks

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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 heterogeneous 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 heterogeneous wireless sensor networks. 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: *wireless sensor network, clustering protocol, energy efficient, heterogeneous.*

1. 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. Heterogeneous 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. The energy saving schemes for homogeneous wireless sensor networks do not perform efficiently when applied to heterogeneous wireless sensor network. 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 heterogeneous wireless sensor networks. We also compare these protocols on various points like, location awareness, clustering method, heterogeneity level and so on.

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. In Section 4 we provide a survey of energy efficient clustering protocols for heterogeneous wireless sensor networks and compare these protocols in section 5. Finally, In section 6 conclusion of the paper is presented.

2. Heterogeneous Model for Wireless Sensor Network

This section presents a paradigm of heterogeneous wireless sensor network and discusses the impact of heterogeneous resources [4,5].

2.1. Types of heterogeneous resources

There are three common types of resource heterogeneity in sensor nodes:

- computational heterogeneity
- link heterogeneity
- energy heterogeneity

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

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.

2.2. Impact of heterogeneity on wireless sensor networks

Placing few heterogeneous nodes in the sensor network can bring following benefits:

Decreasing latency of data transportation: Computational heterogeneity can decrease the processing latency in immediate nodes and link heterogeneity can decrease the waiting time in the transmitting queue. Fewer hops between sensor nodes and sink node also mean fewer forwarding latency.

Prolonging network lifetime: The average energy consumption for forwarding a packet from the normal nodes to the sink in heterogeneous sensor networks will be much less than the energy consumed in homogeneous sensor networks.

Improving reliability of data transmission: It is well known that sensor network links tend to have low reliability. And each hop significantly lowers the end-to-end delivery rate. With heterogeneous nodes; there will be fewer hops between normal sensor nodes and the sink. So the heterogeneous sensor network can get much higher end-to-end delivery rate than the homogeneous sensor network.

2.3. Performance Measures

Some performance measures that are used to evaluate the performance of clustering protocols are listed below.

Network lifetime: It is the time interval from the start of operation (of the sensor network) until the death of the first alive node.

Number of cluster heads per round: Instantaneous measure reflects the number of nodes which would send directly to the base station, information aggregated from their cluster members.

Number of alive nodes per round: This instantaneous measure reflects the total number of nodes and that of each type that has not yet expended all of their energy.

Throughput: This includes the total rate of data sent over the network, the rate of data sent from cluster heads to the base station as well as the rate of data sent from the nodes to their cluster heads.

Figure 1 shows the heterogeneous model for wireless sensor network.

3. Classification of Clustering Attributes

In this section, the set of attributes that can be used to categorize and differentiate clustering protocols of heterogeneous wireless sensor networks are described. Our Comparison of heterogeneous clustering protocols is based on these attributes [4,6].

3.1. Cluster Properties

Cluster Count: Cluster heads are predetermined in some of the approaches. Thus, the number of clusters are preset. Cluster head selection algorithms generally pick randomly cluster heads from the deployed sensors hence yields variable number of clusters.

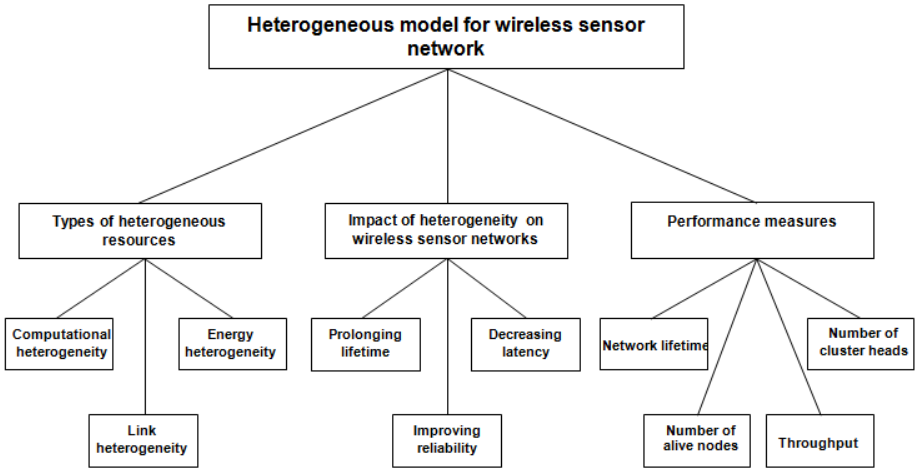

Figure 1. Heterogeneous Model for Wireless Sensor Network

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

Connectivity of cluster head to base station: Cluster heads send the aggregated data to the base station directly or indirectly with help of other cluster head nodes. It means there exists a direct link or a multi-hop link.

3.2. Cluster Head Selection Criteria

Initial energy: This is an important parameter to select the cluster head. When any algorithm starts it generally considers the initial energy.

Residual energy: After some of the rounds are completed, the cluster head selection should be based on the energy remaining in the sensors.

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 current round to keep the network alive.

4. Energy Efficient Clustering Protocols for Heterogeneous Wireless Sensor Networks

Katiyar et al. [4] surveyed clustering algorithms for heterogeneous 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 heterogeneous wireless sensor networks.

4.1. 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.

4.2. Distributed Energy Balance Clustering Protocol for Heterogeneous Wireless Sensor Networks

Changmin Duan and Hong Fan [7] proposed a distributed energy balance clustering (DEBC) protocol for heterogeneous 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.

4.3. Weighted Election Protocol for Heterogeneous Wireless Sensor Networks

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 p_{opt} 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.

4.4. Distributed Energy Efficient Clustering Algorithm for Heterogeneous Wireless Sensor Networks

Qing et al [8] proposed a distributed energy efficient clustering scheme for heterogeneous 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 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. Simulation results show that DEEC achieves longer lifetime and more effective messages than LEACH, SEP and LEACH-E.

4.5. Developed Distributed Energy-efficient Clustering (DDEEC) for Heterogeneous Wireless Sensor Networks

Elbhiri et al. [9] proposed a developed distributed energy efficient clustering scheme for heterogeneous 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 define 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.

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

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.

4.7. Threshold Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Networks

Saini and K. Sharma [2] proposed an energy efficient cluster head scheme for heterogeneous 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.

In TDEEC, the authors have adjusted the value of the threshold, according to which a node decides to be a cluster head or not, based on ratio of residual energy and average energy of that round in respect to the optimum number of cluster heads. Simulation results show that TDEEC performs better as compared to SEP and DEEC in heterogeneous environment for wireless sensor networks.

4.8. Cluster-based Service Discovery for Heterogeneous Wireless Sensor Networks

Marin et al. [11] proposed an energy efficient service discovery protocol (C4SD) for heterogeneous 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).

4.9. Improved and Balanced LEACH for Heterogeneous Wireless Sensor Networks

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. Once the cluster head has all the data from the nodes in its cluster, the cluster head node aggregates the data and then transmits the compressed data:

- To the gateway if :

E CH-to-BS > E CH-to-Gat + E Gat-to-BS

- To the base station if :

E CH-to-BS < E CH-to-Gat + E Gat-to-BS

- E CH-to-BS: total energy dissipated for send data from cluster head to the base station.
- E CH-to-Gat : total energy dissipated for send data from cluster head to the gateway.
- E Gat-to-BS : total energy dissipated for send data from gateway to the base station.

Figure 2 shows The IB-LEACH network model.

simulation results show that IB-LEACH is more energy efficient and is more effective in prolonging the network lifetime and a stability period compared to LEACH and SEP.

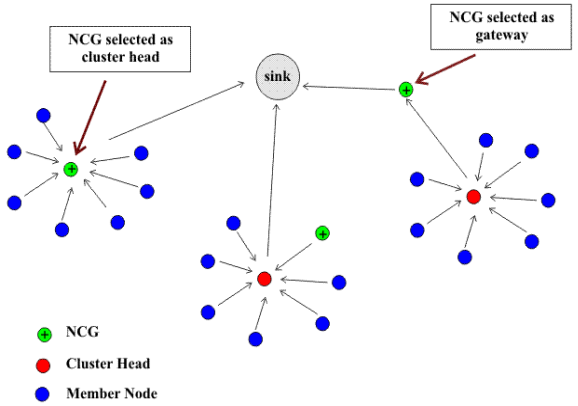

Fig 2. IB-LEACH Network Model [12]

4.10. 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).

4.11. 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.

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

- Nodes in the network are quasi-stationary.
- Nodes locations are unaware i.e. it is not equipped by the GPS capable antenna.
- Nodes have similar processing and communication capabilities and equal significance.
- Nodes are left unattended after deployment.

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.

4.12. Cluster Based Energy Balancing Scheme in Heterogeneous Wireless Sensor Networks

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.

4.13. Cluster Head Relay Routing Protocol for Heterogeneous Sensor Networks

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.

4.14. Energy Efficient Cluster Head Election Protocol for Heterogeneous Wireless Sensor Networks

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.

4.15. Cluster Multi-hop Transmission (CMHT) for Heterogeneous Sensor Networks

Xuegong et al. [17] proposed a new protocol of the Cluster Multi-Hop Transmission (CMHT) for heterogeneous 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.

5. Comparison of the Clustering Protocols for Heterogeneous Wireless Sensor Networks

Table 1 compares the various clustering protocols discussed above on various points like, location awareness, clustering method, heterogeneity level and based on clustering attributes discussed in section 3.

Table 1. Comparison of the Clustering Protocols for Heterogeneous Wireless Sensor Networks

Clustering approach	Clustering method	Location awaren-ess	Hetero g-eneity Type	Heterog eneity Level	cluster head mobility	Clustering Properties			CH Selection based On		
						Cluster Count	Intra-cluster topology	Connectivity of CH to BS	Initial Energy	Residual Energy	Average Energy of Network
EEHC	Distributed	No	Energy	Three	Fixed	variable	Single hop	Direct link	×	✓	×
DEBC	Distributed	No	Energy	Two/ Multi	Micro-mobile/ fixed	variable	Single hop	Direct link	×	✓	✓
WEP	Distributed	No	Energy	Two	Fixed	variable	Single hop	Direct link	✓	×	×
DEEC	Distributed	No	Energy	Two/ Multi	Micro-mobile/ fixed	variable	Single hop	Direct link	×	✓	✓
DDEEC	Distributed	No	Energy	Two	Micro-mobile/ fixed	variable	Single hop	Direct link	✓	✓	×
SDEEC	Distributed	No	Energy	Two	Micro-mobile/ fixed	variable	Single hop	Direct link	✓	✓	×
TDEEC	Distributed	No	Energy	Two/ Multi	Micro-mobile/ fixed	variable	Single hop	Direct link	×	✓	×
C4SD	centralized	Yes	Energy & link	Multi	Mobile	variable	Multi hop	Multi hop	✓	×	×
IB-LEACH	Distributed	No	Energy	Two	Fixed	variable	Single hop	Multi hop	✓	×	×
DCHE	Distributed	No	Energy	Three	Fixed	variable	Single hop	Direct link	✓	×	×
H-HEED	Distributed	No	Energy	Two/ Multi	Micro-mobile/ fixed	variable	Single hop	Direct link	×	✓	×
Jing 2005	Distributed	No	Energy & link	Two	Fixed	preset	Multi hop	Direct link	✓	×	×
CHR	Distributed	Yes	Energy	Two	Fixed	preset	Multi hop	Multi hop	✓	×	×
LI Han 2010	Distributed	No	Energy	Three	Fixed	variable	Single hop	Multi hop	×	✓	×
CMHT	Distributed	No	Energy	Two	Fixed	variable	Multi hop	Multi hop	×	✓	✓

As shown in table 1, each of these protocols uses one of the cluster head selection criteria discussed in section 3 and consider some properties for its cluster. Some of these protocols use single-hop communication for intra/ inter cluster topology and some clustering protocols use multi-hop communication. In some of the protocols, cluster heads are predetermined and the number of clusters are preset and in some other protocols, the number of clusters are variable.

6. Conclusions

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 heterogeneous wireless sensor networks, several protocols are proposed. Most of the recent energy efficient protocols designed for heterogeneous 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 heterogeneous wireless sensor networks and compared these protocols based on clustering attributes. Results of this Comparison have been shown in table 1.

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. Finally, We conclude that the heterogeneous wireless sensor networks are more suitable for real life applications as compared to the homogeneous counterpart.

References

[1] Md. Golam Rashed, M. Hasnat Kabir and S. E. Ullah, "WEP: An energy efficient protocol for cluster based heterogeneous wireless sensor network," International Journal of Distributed and Parallel Systems (IJDPS) Vol.2, No.2, March 2011, pp. 54-60.

[2] P. Saini and A. K. Sharma, " Energy Efficient Scheme for Clustering Protocol Prolonging the Lifetime of Heterogeneous Wireless Sensor Networks," International Journal of Computer Applications (0975 – 8887)Vol. 6– No.2, September 2010, pp.30-36.

[3] D. Kumar, T. C. Aseri and R. B. Patel, "Distributed Cluster Head Election (DCHE) Scheme for Improving Lifetime of Heterogeneous Sensor Networks," Tamkang Journal of Science and Engineering, Vol. 13, No. 3, 2010, pp. 337-348.

[4] V. Katiyar, N. Chand, S. Soni, "A Survey on Clustering lgorithms for Heterogeneous Wireless Sensor Networks" Int. J. Advanced Networking and Applications Vol. 02, Issue: 04, pp. 745-754, 2011.

[5] D. Kumar, T. C. Aseri and R. B. Patel, "EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks," Computer Communications, Vol. 32, 2009, pp. 662–667.

[6] A. A. Abbasi and M. Younis, "A survey on clustering algorithms for wireless sensor networks," Computer Communications 30, 2007, pp. 2826-2841.

[7] C. Duan and H. Fan, "A Distributed Energy Balance Clustering Protocol for Heterogeneous Wireless Sensor Networks," Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. International Conference on, vol., no., 21-25 Sept. 2007, pp. 2469-2473.

[8] L. Qing, Q. Zhu and M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks," Computer Communications, Vol. 29, 2006, pp. 2230–2237.

[9] B. Elbhiri, S. Rachid, S. El fkihi, D, Aboutajdine, "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks", proceedings of 5th International Symposium on I/V Communications and Mobile Network (ISVC), 2010, pp. 1-4 IEEE.

[10] B. Elbhiri, R. Saadane and D. Aboutajdine, "Stochastic Distributed Energy-Efficient Clustering (SDEEC) for heterogeneous wireless sensor networks," ICGST-CNIR Journal, Volume 9, Issue 2, December 2009, pp.11-17.

[11] R. S. Marin-Perianu, J. Scholten, P. J. M. Havinga and P. H. Hartel, "Cluster-based service discovery for heterogeneous wireless sensor networks," International Journal of Parallel, Emergent and Distributed Systems, 2008, pp. 1-35.

[12] B. A. Said and E. Abdellah, "Improved and Balanced LEACH for heterogeneous wireless sensor networks," (IJCSE) International Journal on Computer Science and Engineering Vol. 02, 2010, pp. 2633-2640.

[13] H. Kour and A. K. Sharma, "Hybrid Energy Efficient Distributed Protocol for Heterogeneous Wireless Sensor Network," International Journal of Computer Applications (0975 – 8887) Vol. 4, No.6, July 2010.

[14] J. Ai, D. Turgut, L. Bölöni, "A Cluster-based Energy Balancing Scheme in Heterogeneous Wireless Sensor Networks",. Proceedings of the 4th International Conference on Networking (ICN'05), Reunion, France, April 2005, pp. 467-474

[15] X. Du, F. Lin, "Improving Routing in Sensor Networks with Heterogeneous Sensor Nodes", Proceedings of IEEE 61st Vehicular Technology Conference, VTC, Vol. 4, 2005 pp. 2528-2532.

[16] LI Han, "An Energy Efficient Routing Algorithm for eterogeneous Wireless Sensor Networks", Proceedings of th International Conference on Computer Application and System Modeling (ICCASM 2010), pp. V3-612-V3-616, IEEE, 2010.

[17] Q. Xuegong, M. Fuchang, Ch.Yan, Y. Weizhao, "The Protocol of Cluster Multi-Hop Transmission Based on Heterogeneous Wireless Sensor Networks", proceedings of International Conference on Computational Intelligence and Software Engineering, CiSE 2009. pp. 1-4, IEEE.

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