STUDY AND COMPARISON OF DISTRIBUTED ENERGY EFFICIENT CLUSTERING PROTOCOLS IN WIRELESS SENSOR NETWORK: A REVIEW

By

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ABSTRACT

In the past years, the wireless sensor networks are a emerging and trending technology because of its interesting applications to replace humans to monitor the physical and environmental conditions in industrial, civilians and military uses. The sensor nodes are battery operated, therefore these networks are energy constrained. An optimum trade-off is required in between energy dissipation, accuracy and latency in data transmission in Wireless Sensor Networks for longer network lifetime and effective message or throughput. The main goal of Research in Wireless Sensor Network is to devise novel energy efficient routing solutions to save the energy of motes, thereby maximizing the lifetime of sensor nodes. Topology control or clustering of sensor nodes can balance the load among sensor nodes, which increases the network lifetime and the scalability period of sensor nodes in Wireless Sensor Network. This paper provides a review on various hierarchical energy efficient clustering protocols along with the applications of the Wireless Sensor Networks.

Keywords: CH, SN, Heterogeneous, WSNs, DEEC, EDEEC, DDEEC.

INTRODUCTION

Wireless Sensor Networks (WSN) have become very prominent in recent years, because WSNs have an enormous and very beneficial uses across a wide range of medical, industrial, scientific, battlefield awareness and environmental applications. As in Military application, sensor networks can be used for guarding and in surveillance borders from intruding the restricted regions, smuggling, nuclear or chemical attack detection etc., using sensors. Because of global warming, the glaciers are melting, which further causes flooding of the rivers. This can be easily detected by monitoring a river's water level regularly by sensor deployment on glaciers and river banks [20]. Poaching of extinct species in forests is very common. It can be prevented using the RF collars to track and monitor the animals; sensors can also be deployed for monitoring the forests all time. Therefore, WSNs are very beneficial in many ways and will be more advantageous due to interesting applications in the coming years of research in this field.

The Wireless Sensor Networks are composed of sensors (also called motes), which communicate in a wireless manner for data transmission over an area. The sensor nodes can vary in number from a few to thousands accordingly to the WSN application, where each sensor node is connected to one (or several) other sensors. A sensor node generally consists of sensing unit, power unit, transceiver unit and the processing unit.

Clustering in WSNs is a technique to increase the lifespan of the network, therefore researchers have used different types of clustering of the sensors to design, new energy efficient routing protocols. Sensors in WSNs sense the environmental conditions, then send the sensed data to the Cluster Head (CH). The CH then forwards the data either to a common processing centre called Base Station Sink via multiple hops to the base station or directly if the network adopts single hop clustering. Single hop clustering means that a sensor node in a cluster directly

forwards the sensed data to the CH as they are directly connected to the CH. On the other hand, multiple hops clustering means that, the sensor node relays the data via other sensor nodes, which then forward data to the CH. The cluster head aggregates and compress the sensed data by removing redundancy and then sends it to the BS. This mechanism of data fusion and compression save the energy of the sensor nodes by reducing the unnecessary data transmission to the final processing node [22-28]. The basic Architecture of a Wireless Sensor Network with Clustering is shown below in Figure 1.

There are some limitations of the sensor's physical structure, which caused many challenges in fabricating the Wireless Sensor Networks [21,22]. Some of these limitations which affect the deployment of the Wireless Sensor Network are as follows.

- Limited energy or battery life.
- Limited transmission range.
- Small storage size.
- Network dynamics and Node deployment.

1. Need for the Study

Wireless sensor technology has several interesting applications like as mentioned in the section Wireless Sensor Network Applications. This review paper incorporated all the latest routing protocols of WSN up to 2015 related to distributed energy efficient clustering protocols in Wireless Sensor Networks. So this paper gives a summarized form of all researches based on distributed clustering protocols in both homogenous and heterogeneous Wireless Sensor Network environment which can be useful for research scholars to develop new protocols in WSN. The current Research and Development (R&D) field is to develop low-power communication protocols with inexpensive on-node processing and limited power supply. The authors have also studied these protocols in a comprehensive manner, in order to make a new energy efficient protocol, which exploits the best features of these clustering protocols which are reviewed in this paper.

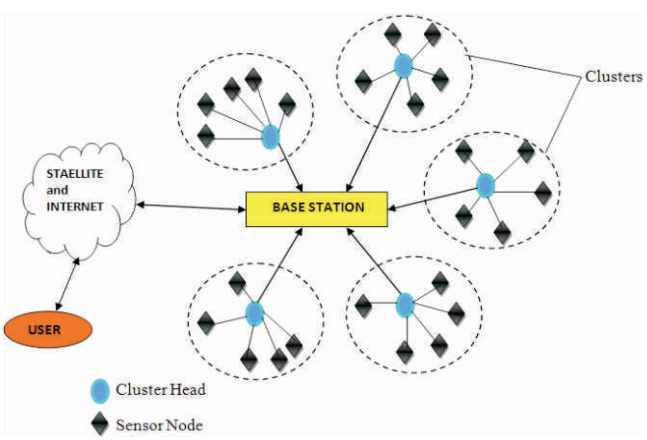

Figure 1. Basic Architecture of a Wireless Sensor Network with Clustering

2. Classification of the Routing Protocols in Wireless Sensor Networks

Routing is a process of searching a path between the source node and the final processing node (Sink or Base Station) for the transmission of data. Many new hierarchical clustering protocols are designed especially for the sensor networks, where energy consumption is an essential concern to increase the lifetime of the sensor nodes. This review paper focus on the study of hierarchical cluster based energy efficient protocols in different environments of a Wireless Sensor Network. The hierarchical protocols can be classified into subclasses: the homogeneous clustering (same energy levels) and heterogeneous clustering schemes (different energy levels), where all the nodes of a sensor network are equipped with different amount of energy [24]. The taxonomy of the hierarchical routing protocols in WSNs is shown in Figure 2.

Hierarchical routing protocols firstly create the clusters and the cluster heads in WSN, then the routing is

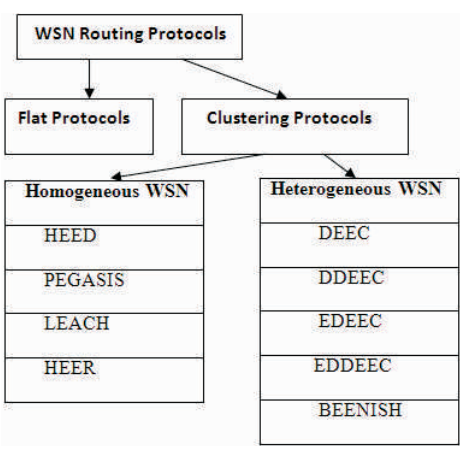

Figure 2. Taxonomy of Hierarchical Routing Protocols in WSN

performed. Each cluster head is responsible for organizing communication in a cluster, and makes the sensed data of the cluster to get compressed, and then aggregates it and makes the data free from unwanted redundancy. The hierarchical routing protocols are the best solution for increasing the lifetime and reducing the energy dissipation of the network. There are many hierarchical routing protocols have been proposed in the past years, which are as follows:- LEACH, TL-LEACH, HEED, HEER, TEEN, APTEEN, ACH, PEGASIS, SEP, T-SEP, ZSEP, DEEC, EDEEC, DDEEC, TADEEC, TDEEC, EECS , EDDEEC, BEENISH, and many more. Some of these protocols have been reviewed in this paper.

3. Literature Review

W.R. Heinzelman et al. [1] in 2000, introduced the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, which is one of the first and popular clustering protocols. LEACH is for homogeneous Wireless Sensor Network, which means all the sensors in the network have same energy. In LEACH, all the clusters are elected on a probability function. If the value of the probability function is less than the threshold, then the current node will be elected as a cluster head. To balance the energy consumption, cluster head randomly rotates over time.

A. Manjeshwar and D.P. Agrawal [2] in 2001, proposed TEEN (Threshold-sensitive Energy Efficient Network) protocol for WSNs. TEEN is a location aware protocol and was developed for reactive networks and time critical applications. TEEN incorporates the same concept of LEACH for cluster formation and CH selection of nodes. TEEN have two types of threshold in protocol, viz., Hard Threshold (HT), and Soft Threshold (ST) along with the current sensed value. The TEEN protocol sends the value of sensed parameter to the base station, when there is a sudden and significant change in the threshold value of that parameter, greater than or equal to the set threshold value, where the sensor node switches on its transmitter to send the required information to the base station. On simulation, TEEN outperforms LEACH and LEACH-C on average energy dissipation and the total number of alive nodes metric.

A. Manjeshwar and D.P. Agarwal, [3] in 2002, proposed APTEEN, an enhanced version of TEEN (Threshold-sensitive Energy Efficient sensor Network) protocol, which sends the sensed periodical data at regular time interval, and can be used in both applications either proactive or reactive. APTEEN has a disadvantage over TEEN that it consumes more energy than TEEN.

S. Lindsey et al. [4] in 2002, introduced PEGASIS (Power Efficient Gathering in Sensor Information Systems) in this paper. The authors have proposed a chain based structure of clustering and it is an improved version of LEACH. In PEGASIS, the nodes form a cluster in a chain-like structure, which supports multi hop relaying employed for data transmission. A node sends its data to its nearest node in the chain, and the node keeps forwarding the required information to its neighbour node in the chain until the data reaches the sink.

Georgios Samaragdakis et al. [5] in 2004 devised SEP (Stable Election Protocol) for clustered heterogeneous Wireless Sensor Networks. SEP is a two level of energy aware (normal nodes and advance nodes) protocol in heterogeneous WSN. In SEP, the cluster head election is based on the weighted probability with respect to energy of the nodes. The advanced nodes have more chances to become CH. Stable Election Protocol does not consider the remaining energy of the node in CH election. So this is a disadvantage of the SEP, as it keeps on punishing the advanced nodes to become a CH.

Ossama Younis and Sonia Fahmy [6] in 2004 proposed HEED (Hybrid Energy-Efficient Distributed), which is an improved clustering approach for Ad-hoc Sensor Networks. The authors proposed the protocol, HEED which elects the CH periodically by the remaining energy level of the node and the node degree (number of nodes connected to that node). The simulation shows a comparison that the HEED outperforms LEACH in terms of sensor network lifetime and scalability of data aggregation.

Li Qing et al. [7] in 2006, presented a DEEC (Design of a distributed Energy-Efficient Clustering) algorithm for heterogeneous Wireless Sensor Networks, which is a hierarchical protocol for two or more energy levels in

heterogeneous WSNs. DEEC protocol distributes the high energy task of cluster heads among all the nodes in a network, according to their residual energy and initial energy of the nodes. There are two types of nodes, viz., normal and advance. The advance nodes have (1+a) times more energy. So the advance nodes have a high initial and residual energy, and therefore they have a greater probability for being selected as a CH. CH election is based on a probability function, which is a ratio of current node residual energy and the average network energy.

B. Elbhiri et al. [8] in 2010, proposed DDEEC (Developed Distributed Energy-Efficient Clustering) for heterogeneous Wireless Sensor Networks, which works 15% better than DEEC. The average probability, p_i to be a cluster head is changed in DDEEC, which removes the DEEC protocol's penalizing effect to deplete the energy of only advance nodes or higher energy nodes. So, in this way, DDEEC outperforms DEEC and increase the lifetime of a network.

Parul Saini and Ajay K. Sharma, [9] in 2010, introduced E-DEEC (Enhanced Distributed Energy Efficient Clustering) algorithm for heterogeneous Wireless Sensor Networks. In E-DEEC, the authors have increased the heterogeneity level of the network from two to three by inserting a new type of node called a super node. The super node in the network has (1+b) times more energy than the normal nodes. E-DEEC inherits the principle of DEEC in CH selection and formation of clusters. On comparison, with SEP, EDEEC gives better results in terms of stability and lifetime of a network.

Parul Saini and Ajay K. Sharma, [10] in 2010, developed a TDEEC (Threshold Distributed Energy Efficient Clustering) protocol. TDEEC is an improved variant of DEEC, which has a three level energy heterogeneity. In TDEEC, the authors have changed the threshold function by inserting a new variable i.e. k_{opt} function (optimum number of cluster heads). In TDEEC approach, the node is elected as a CH on the basis of ratio of residual energy of a node to average energy of the Wireless Sensor Network with respect to k_{opt}. TDEEC outperforms the SEP and EDEEC on the energy and throughput metrics.

N. Javaid et al. [11] in 2013, proposed EDDEEC (Enhanced Developed Distributed Energy-efficient Clustering) for Heterogeneous Wireless Sensor Networks. This approach is an enhanced version of EDEEC and DDEEC named as EDDEEC (Enhanced Developed Distributed Energy Efficient Clustering). EDDEEC, removes the penalizing effect of DDEEC and has three types of energy nodes in EDEEC heterogeneous WSN. On simulation, it shows better results than previous algorithms.

T.N. Qureshi et al. [12] in 2013, devised BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous) Protocol for Wireless Sensor Networks. In BEENISH, the Cluster Heads (CHs) are elected on the basis of residual energy level of nodes and the average energy of the network. Four energy levels of the nodes have been proposed in WSN, where the new fourth level energy node group is ultra super nodes that has a high energy level in WSN. Simulation results show that, it outperforms better than DEEC variants.

Anamika Chauhan and Amit Kaushik [13] in 2013, introduced TADEEC (Threshold Sensitive Advanced Distributed Energy Efficient Clustering Routing) Protocol for Wireless Sensor Networks. In this paper, the authors present a super advanced node with the existing three types of nodes likewise in EDEEC. They also used the concept of TEEN (reactive protocol) in TADEEC with four levels of heterogeneity. TADEEC outperforms LEACH, DEEC and EDEEC on lifetime and stability parameter.

N. Javaid, et al. [14] in 2013, proposed HEER (Hybrid Energy Efficient Reactive) Protocol for Wireless Sensor Networks. The authors developed a protocol for homogeneous and reactive wireless sensor network. This protocol is not energy aware about the energy of the network. It incorporates the features of DEEC and TEEN protocol. From DEEC, HEER protocol uses the CH election technique based on the residual energy of the nodes in WSN, and from TEEN it uses the hard and soft threshold concept.

N. Javaid et al. [15] in 2013, introduced ACH (Away Cluster Heads) protocol in WSNs for achieving energy efficiency. The authors have proposed a scheme for a new

arrangement of sensor nodes in a way that, two cluster heads are maintained a distance of 12 m minimum. So in this way, the CHs are distributed in a balanced manner in a Wireless Sensor Network. ACH scheme is applied on LEACH, SEP and DEEC, and then compared with conventional LEACH, SEP and DEEC protocols. On comparison, LEACH-ACH, SEP-ACH and DEEC-ACH give better results in terms of stability and the number of packets sent to the Sink.

G. Chandini, and Rajavali Guntur, [16] in 2014, introduced an Energy Efficient Zonal Stable Election Protocol for WSNs, where they categorized the network into three regions. One zone in the network contains normal nodes and the remaining other two zones contain the advance nodes according to their energy levels. The base station deployed in the centre is stationary in the sensor area. If the normal nodes want to send their sensed data to BS, they have the privilege of direct communication to BS. If the node comes in the other two zones which have the advance nodes will forward the data to CH and relay their data to BS through the CH. ZSEP shows better results from the existing protocols in terms of energy metrics.

Manpreet Kaur et al. [17] in 2014, introduced TLH-DEEC (Two Level Hierarchical Distributed Energy-Efficient Clustering) scheme with increased heterogeneity in Wireless Sensor Network. TLH-DEEC protocol is an enhancement of LEACH in which, the authors have used a two level cluster head. The primary CHs are elected on the residual energy of a node and secondary CHs are selected from the primary cluster heads. TLH-DEEC outperforms conventional LEACH, DEEC and SEP on lifetime metric of a network.

Amarjit Kaur and Simarjeet Kaur, [18] in 2015, proposed IBEENISH (Improved Balanced Energy Efficient Network Integrated Super Heterogeneous) protocol, which is an enhancement of BEENISH and uses the same concept with an increased heterogeneity in energy levels of the nodes. IBEENISH has a new energy level with four existing types of level of BEENISH in heterogeneous WSN. The IBEENISH has a new node name known as a super-ultra-super node.

Mansi Panwar and S.D. Samantaray [19] in 2015, proposed PTEDEEC called as Periodic Threshold Sensitive Distributed Energy Efficient Clustering protocol. The network of PTEDEEC is not location aware, which means it cannot send its position information to the CH. It uses the best features of APTEEN and EDEEC with three levels heterogeneity in sensor nodes i.e. three different types of energy are presented in the sensor nodes. By employing the APTEEN concept, the author applies a new approach for periodic and threshold data transmission which improves the EDEEC protocol.

4. Review of Clustering Protocols in Wireless Sensor Networks

Table 1 depicts the comparison on different metrics in the clustering protocols in WSN.

5. Wireless Sensor Network Applications

5.1 Traffic Management

- In providing information about special weather conditions to the drivers.
- In route planning [25].
- To detect the traffic jams in the city.
- In vehicle tracking and planned parking lot detection.
- Monitoring vehicle speed.

5.2 Home Applications

- In fire detection.
- In electric and water consumption.
- Detection of water leakage in pipes.
- In home automation.

5.3 Healthcare Applications

- In drug administration of patients in wards.

Protocol	Energy levels	Network Lifetime	CH Mobility	Location Awareness	CH election by Residual energy
LEACH	One	Poor	Fixed	No	No
TEEN	One	Best	Fixed	Yes	No
SEP	Two	Good	Fixed	No	No
DEEC	Two	Better	Fixed	No	Yes
DDEEC	Two/Multi	Good	Fixed	No	Yes
TDEEC	Three	Good	Fixed	No	Yes
EDEEC	Three	Good	Fixed	No	Yes
EDDEEC	Three	Good	Fixed	No	Yes
TADEEC	Four	Good	Fixed	No	Yes
BEENISH	Four	Best	Fixed	No	Yes
IBEENISH	Five	Best	Fixed	No	Yes

Table 1. Comparison of different metrics of Clustering Protocols in Wireless Sensor Networks

- Monitoring the patients in ICU, where patients need care all time.
- Tracking the doctors and patients inside the hospital.
- Various gadgets are available now which monitors the several activities like, walking steps and calorie burning via Fit Bit bands using NFC technology.

5.4 Commercial Applications

- In industrial monitoring, for example cold storage, for ripening of fruits (temperature sensing)
- For environmental controls like Humidity, Ventilation, Air Conditioning (HVAC) in industrial, educational and office buildings.
- Inventory control (in stocking of various goods) of medicines and electronics.

5.5 Environmental Applications

- In disaster management.
- In flood detection.
- In fire detection and prevention.
- In Earthquake detection by seismic and pressure sensors.
- In Biodiversity mapping of wildlife by sensors.
- Managing the rearing condition of animals on farms.

5.6 Military Applications

- In estimation of a battle damage.
- In arsenal and ammunition detection.
- In guarding the boarders from infiltration and smuggling by motion sensors.
- In monitoring the restricted and sensitive attack places, where soldiers can't be guarded.
- Guarding sea and sky by sonar and radar technology.
- In Radiation prevention of nuclear or harmful radiation that occurs accidently or intentionally.

5.7 Smart Agriculture

- To manage crop cultivation by sensors.
- In detecting the risk of frost, and plant diseases.
- In sensing the humidity, sunlight and temperature of the green house's environment.
- In predicting the irrigation requirements of the plants.

5.8 Structural Health Monitoring

- Regular monitoring of large structures like bridges, buildings and roads for ensuring public safety.

Conclusion

The main concern of research in WSN is to devise the new energy efficient protocol which gives the optimal energy solution for WSN. So in this paper, various energy efficient protocols are reviewed. The main objective of these protocols is to reduce the energy dissipation in sensing, processing, aggregation or compression of data and data transmission. The energy consumption in these protocols are reduced by distributing the tasks among all the nodes, making the sensed data redundancy free, thereby the data is compact. Only a lesser data have to be transmitted and also by the deployment of the sensor nodes in a distributed manner, a particular distance is maintained from the CH and Base Station. Hence the authors conclude that, in homogeneous clustering and heterogeneous clustering protocols, the heterogeneous clustering protocols perform better in prolonging the network lifetime, stability and throughput.

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