

## **Cluster Based Routing Protocols in Wireless Sensor Network:**

### **A Comparative Review**

Shraddha Agrawal<sup>1</sup>, Rajeev Pandey<sup>2</sup>, Mahesh Motwani<sup>3</sup>

Department of Computer Science and Engineering, UIT-RGPV, Bhopal<sup>1,2,3</sup>

45shraddha@gmail.com<sup>1</sup>, rajeev98iet@gmail.com<sup>2</sup>, mahesh.bpl.7@gmail.com<sup>3</sup>

**Abstract--** Wireless sensor network (WSN) is a collection of sensor nodes that together collect the information. WSN lifetime depends on battery power. Each sensor node has non-rechargeable battery. So enhancement of energy efficiency is the important objective of WSN design. Several energy efficient clustering protocols are designed to cluster the nodes and define one powerful node called as cluster head (CH). In this paper we have done the comparative study of various CH selection protocols.

**Index terms-** Wireless sensor networks, routing, clustering.

#### **I. INTRODUCTION**

WSN is a collection of many independent devices known as sensors, which is used to monitor conditions like temperature, humidity etc. These sensor nodes are distributed in random manner. WSN has been used in wide range of applications such as military surveillance, traffic monitoring, environmental monitoring and medical monitoring etc. Many factors affect the working of WSN such as routing.

These nodes are deployed in the environment where it is difficult for humans to reach easily. Therefore communication between the nodes should consume minimum power for the betterment of network lifetime.

The limitation of resources such as communication bandwidth and energy influence the design of a routing protocol to efficiently use the available resources.

WSN have a very large number of small resource devices, but these devices work together to perform a single task for which network is designed. There are various sensors which are distributed in particular region. These sensor nodes sense the environmental parameters and then they convert it into the digital form. This sensed data is then processed by the sensor node and then they transmit it to the neighbor node. Data sensed by one node is passed through multiple nodes in a way to reach the last node which is known as sink node. Then sink node sends the collected information to the end user [12].

These networks have three architectures

1. Distributed Architecture: In this architecture all nodes are scattered in sensor field to monitor environmental parameters for further processing.
2. Hierarchical Architecture: In this architecture nodes at the top known as gateway. This gateway is connected to other nodes via different paths in such a way that there are no closed paths.
3. Clustered Architecture: In this architecture network is partitioned into smaller area known as clusters. Each cluster has a special node known as cluster head (CH) and other nodes are called member nodes. Data sensed by the member nodes is passed to the CH and then CH aggregate all information for transferring to the sink. It has significant advantages in energy saving and scalability.

The remaining paper is structured as follows: In section 2, we discuss various routing techniques in WSN. Then, section 3 described various clustering strategies. Section 4 analyzes various clustering protocols and section 5 concludes this paper.

## II. ROUTING TECHNIQUES IN WSN

Routing is a data propagation technique where nodes try to find optimal path to transmit the data. There can be multiple paths from source to the sink. Routing technique selects the best path. Routing protocols are classified as Direct Communication, Flat and Clustering Protocols [2] [13]. Direct Communication: In this protocol all the nodes in a network can send data directly to the sink node. Because of this long distance communication the energy consumed by the nodes is very high and the scalability is also restricted.

Flat Protocol: Any node who wants to send data to sink, first searches for a valid path and then transmit data through it. The disadvantage of this technique is, nodes near the sink get drained out quickly.

Clustering Protocol: In this type of protocol network is divided into small size clusters. Nodes belonging to the cluster select one cluster head among them and send data to it. CH then communicates with sink.

## III. CLUSTERING STRATEGY

In WSN, if all the nodes directly transmit the data to the sink without proper coordination then this will impose a heavy load on network. Also redundant information is passed to the sink as a result of this redundancy elimination, data aggregation work at sink increases. Energy consumption of a network is also very high and scalability is restricted. To overcome these challenges a network is divided into smaller size clusters [3] [10].

Figure 1 clearly explains the communication among the CH, member node and sink.

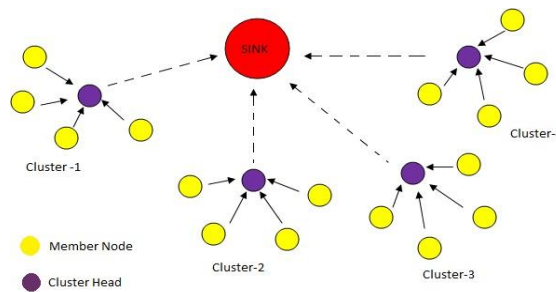


Fig. 1: Clustering Scenario

## IV. CLUSTERING PROTOCOLS

### 1. LEACH

LEACH [4] is a first hierarchical protocol introduced by W.R. Heinzelman, et.al., in the year 2000. The working of LEACH is mainly divided into two phases. In first phase all the nodes decide among themselves to become a CH. This is based on two options i.e, 1. how many times a node has been selected for the CH job. 2. how many CHs are required for this round. Based on the above two points, node selects a random number between 0 and 1. Each node decides this independently. Mathematically the threshold value is calculated as below-

$$T(n) = \frac{P}{1 - P \times (r \bmod P^{-1})} \quad \forall n \in G$$

$$T(n) = 0 \quad \text{Otherwise}$$

Where n = node,

P = desired probability of a node to become CH,

r = current round number and

G is the set of nodes that weren't CHs in the last 1/P rounds.

Every node in LEACH generates a random number between 0 and 1. If the generated random number is less than a threshold value, a node become the CH. The function is a combination of two factors. First is how often a particular node is chosen a CH in the past and the optimal number of CH required in a network. Therefore CH selection is based on random round robin.

## **2. EECS**

Ye, Mao, et al have proposed EECS[5] in WSN. It is a load balanced, distributed and energy efficient clustering algorithm. In EECS the eligible CH candidates compete to become a CH for a given round by broadcasting it's residual energy to the neighbouring nodes. If its residual energy is more than the energies of other nodes then it became the CH. The difference between LEACH and EECS is that EECS extends the LEACH algorithm by considering the distance of a cluster from the base station (BS). This is achieved by broadcasting a "hello" message by the BS to all the nodes with a certain power level. From the signal strength received, each node computes its approximate distance from the BS. This increases distribution of energy in a network. The energy consumptions of the sensor nodes is distributed during the phase of cluster formation to increase the network life time. There is a single hop communication between CH and BS.

## **3. EDIT**

Thakkar and K. Kotecha, have proposed an algorithm called EDIT [7] for CH selection using energy and delay constraint for WSN. EDIT optimizes the performance based on two parameters: energy and delay. This protocol provides more scalability to the network. EDIT algorithm selects the CH and "next hop" node by considering two parameters namely: energy and delay requirement. This protocol demonstrate the effect of two types of distances known as Euclidean distance and Hop count between CH and its member nodes which is used to elect CHs. The selection of next hop node in a multi-hop communication affects the total energy and delay requirement.

## **4. SEECH**

SEECH developed by Mehdi Tarhani, et. al [8] is a distributed algorithm suitable for applications deployed to monitor harsh and remote environment. It classifies the network in three layers namely: member nodes, CHs and relay. If the same node acts as a CH as well as relay node then energy consumption will be high because not only CH will handle the data from its own cluster but also from the neighbouring clusters. Node will behave as a CH or relay depends upon the nodes eligibility. Using the nodes eligibility the high degree nodes are selected as a CH and low degree nodes are selected as a relays.

## **5. HEED**

O. Yonnis et.al present a protocol HEED [6], that is based on two factors: node residual energy and physical distance between the nodes. It checks residual energy of every node to select initial set of CHs. It selects the final CH with the help of intra-cluster communication cost. This two level method is useful in resolving the ambiguity when a node is present within the range of multiple CHs. In HEED it is very important to know the power level of a node. This is known as cluster power level. Low cluster power level is good for intra-cluster communication

and high cluster power level is required for inter-cluster communication. Therefore in cluster formation process, whenever any node wants to select a cluster, it calculates the intra-cluster communication cost with the other CHs and joins the cluster with lowest cost. This intra cluster communication cost can be measured using Average Minimum Reachability Power (AMRP) measurement. It is the average of minimum power levels of each node in a cluster. Using AMRP to select CH is more beneficial than selecting the nearest CH. This approach is called as hybrid because it uses residual energy to probabilistically select the CH and uses communication cost as a second parameter for joining nodes with the cluster.

## **6. FSC**

Hai Lin et.al proposed a new clustering protocol called FSC[1]. This protocol partition the network into fan shape clusters. Using FSC better energy saving and packet collection rate (PCR) can be achieved as compare to hybrid technique and distributed clustering[1]. Inside fan-shaped structure CH is selected using random back-off time mechanism.

## **7. WCA**

Lu Cheng, Depei Qian and Weiguo Wu, proposed a weighted clustering algorithm [9] to improve the cluster formation process of LEACH by considering work load balance, mutual position, residual energy and MAC functioning. This method considers energy, distance and node degree for selecting the best CH. In this approach energy consumption is minimized by reducing distance among CH, cluster members and base station.

## **8. TEEN**

TEEN [11] is developed by combining hierarchical and data centric protocols. It is designed for time critical applications. It first creates cluster and CHs broadcast two thresholds in the respective clusters. These two thresholds are known as hard threshold value and soft threshold value. Hard Threshold is a hard value of a parameter after which if the node sense these values than the node must report it to the respective CH. And Soft threshold is a small change in the parameter that has to be reported. A node in a WSN using TEEN will transmit data only when the received parameter is above the hard threshold or the value changed in simulation environment is beyond soft threshold. The main drawback of this algorithm is that it should not be used for networks which require periodic transmission of readings to the sink, because the values may not fulfill the criteria of hard threshold and soft threshold all the time. TEEN protocol encourages the message transmission between the CHs only. If the CHs are not in transmission range the message will not be delivered.

## **9. APTEEN**

APTEEN [14] is the next version of TEEN protocol to collect periodic and time critical data. CHs transmit threshold value and transmission parameter to member nodes. In APTEEN, CH has given an additional role of data aggregation. It supports different types of queries: analyzing historical data, taking the quick view of a current network and continuously observe a particular schedule for sometime.

## **10. PEGASIS**

PEGASIS [15] is a data collection and chain based protocol. Energy can be saved if nodes don't form clusters directly. This is achieved by creating chain pattern and continuous data aggregation is performed across the chain. If chain is established from source node to sink node for transmission, than only last node will be able to interact with the sink. The network lifetime is increased by using PEGASIS because nodes transmit information to their closest neighbor and they have a chance to communicate with the sink node. This technique reduce the power consumption because in every round different node is selected for interaction with base station.

## **11. ER-HEED**

HEED based technique ER-HEED [16] has been proposed by considering the CH selection frequency, network density and the node coverage. ER-HEED works as cluster formation module and CH is selected using HEED protocol. In ER-HEED the current CH assign its role to another node which has maximum energy without any re-election process. After the nodes started dying, the new CH is selected by re-clustering process. Rotation of CH role without performing the re election saves the time and energy.

## **12. EEFL-CH**

EEFL-CH [17] uses fuzzy logic for CH selection. This approach is an extension of LEACH protocol. EEFL-CH is based on three parameters: total residual energy, desired efficiency and the range of nodes from the BS. In each round the nodes calculate their chances of becoming CH based on three fuzzy parameters mentioned above. Node is selected as a CH if the maximum chance to become the CH is low than the threshold value.

## **13. ECHS**

The Energy-efficient Cluster Head selection (ECHS) [18] protocol is proposed for cognitive radio sensor networks (CRSNs). In ECHS protocol, the energy-efficient clustering is achieved by considering the dynamic channel access nature of CRSNs. In this protocol, selection of a cluster head depends on two factors: the availability of channel in the node coverage and the node residual energy. Each node is aware with the availability of free channels. The node is selected as a CH, who poses a larger number of available free channels and more residual energy.

#### 14. RF-LEACH

RF-LEACH [19] uses rough fuzzy c means (RFCM) for the partitioning procedure and fuzzy logic for CH selection. Cluster based hierarchical routing protocol RF-LEACH is an extension of LEACH protocol. The rough fuzzy c means (RFCM) is the combination of rough set theory and fuzzy c mean (FCM). The partitioning and choice of CH will provide significant effect in the network lifetime. The clustering is done by BS using RFCM after determining the optimal number of clusters and this information is broadcasted to the nodes. The clustering is done once at BS and it is fixed throughout the network lifetime. A fuzzy inference system (FIS) is used for the election of CH by the BS depends on two parameters residual energy and distance from the BS.

#### 15. FLCP

The fuzzy logic clustering protocol (FLCP) [20] focus on energy level of each node, bandwidth and link efficiency. The CH node is selected based on highest probability of energy among the nodes in the clusters.

Then remaining nodes are associated with respective CHs. Finally the processing of data is performed using fuzzy logic. Table 1 presents the Comparative Study of the above mentioned algorithms.

**Table 1: Comparison of Different Clustering Protocols**

| Sr. No. | Protocol Name | Authors                                                       | Metrics considered for CH selection                                                                  | Advantages of the protocols                                                                  | Dis-advantages of the protocols                                                                    |
|---------|---------------|---------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| 1.      | LEACH [4]     | W.R Heinzelman, et.al (January 2000)                          | Percentage of optimal CHs in a network and how often in last time the given node is selected as CHs. | Rotates the CH job between the available nodes                                               | Performance degradation for uneven node distribution                                               |
| 2.      | EECS [5]      | M. Ye, C. Li, et al. (IEEE, April 2005)                       | Residual energy                                                                                      | Load balanced, distributed, energy efficient, focused on periodic data collection            | EECS has more control overhead complexity since all the nodes compete with each other to become CH |
| 3.      | EDIT [7]      | A. Thakkar and K. Kotecha (IEEE, August 2014)                 | Energy and delay                                                                                     | Improved scalability of network, used in time critical applications                          | Considers energy and delay parameters only. Other parameters may also be focused                   |
| 4.      | SEECH [8]     | M. Tarhani, et al, (IEEE, November 2014)                      | High degree nodes selected as CH and low degree nodes selected as relay node                         | Separate the role of CH and relay node to improve energy efficiency                          | Additional overhead in maintaining two different types of roles for CH and relay nodes             |
| 5.      | HEED [6]      | O. Younis and S. Fahmy (IEEE, October - December 2004)        | Residual energy and AMRP                                                                             | Multi hop clustering algorithm, control overhead is minimized during CH selection            | CH near the sink may die earlier due to heavy workload                                             |
| 6.      | FSC [1]       | Hai Lin, Lusheng Wang, and Ruoshan Kong (IEEE, December 2015) | Fan shaped clusters and random back off time                                                         | Robust routing, relay selection, efficient cluster head selection and handles hotspot issues | CH is selected based upon random back off time in fan shaped structure                             |

|     |               |                                                                           |                                                                              |                                                                                             |                                                                                             |
|-----|---------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| 7.  | WCA [9]       | Lu Cheng, Depei Qian and Weiguo Wu (IEEE, December 2008)                  | Energy, distance and node degree                                             | It is distributive in nature to prevent the CH overload                                     | All the nodes in network must know the weights of all other nodes before starting           |
| 8.  | TEEN [11]     | Manjeshwar, Arati, and Dharma P. Agrawal (2001)                           | Hard threshold and soft threshold                                            | Data transmission is controlled more accurately                                             | Not suited for applications where consistent data is needed                                 |
| 9.  | APTEEN [14]   | Manjeshwar, Arati, and Dharma P. Agrawal (IEEE, 2002)                     | Combination of LEACH and TEEN                                                | Combination of proactive and reactive policies                                              | More processing is needed to implement count logic and threshold                            |
| 10. | PEGASIS [15]  | Bandyopadhyay, Seema, and Edward J. Coyle (IEEE, 2003)                    | Creation of a chain like structure                                           | It decreases the the quantity of data transmission through information aggregation in chain | Excessive delay as information has to travel through chain for two distant nodes            |
| 11. | ER-HEED [16]  | Ullah, Zaib et al., (IEEE, 2016)                                          | CH selection frequency, network density and the node coverage                | Improves HEED by introducing rotation parameter in equal sized cluster                      | When any of the node dies, entire re-clustering process is executed                         |
| 12. | EEFL-CH [17]  | El Alami, Hassan, and Abdellah Najid (IEEE, 2016)                         | total residual energy, desired efficiency and the range of nodes from the BS | Fuzzy logic is capable of handling uncertainties                                            | Time complexity of the algorithm is more as it involves more comparisons in form of if-else |
| 13. | ECHS [18]     | Helal, Emad, Ahmed Khattab, and Yasmine A. Fahmy (IEEE, 2016)             | Availability of channel in the node coverage and the node residual energy    | It handles the hot spot issue                                                               | More desirable for high data rate applications                                              |
| 14. | RF-LEACH [19] | Mondal, Sanjoy, Pratik Dutta, Saurav Ghosh, and Utpal Biswas (IEEE, 2016) | Residual energy and proximity to BS                                          | Takes advantage from rough fuzzy c means and fuzzy inference systems both                   | Works with fixed Base station                                                               |
| 15. | FLCP [20]     | Bhajantri, Lokesh B., and Ashok V. Sutagundar (IEEE, 2016)                | Highest probability of energy among the nodes                                | Probabilistically selects the CH to achieve better results                                  | Involves more computation                                                                   |

## V. CONCLUSION

Efficient energy utilization is a very important issue in WSN. Various clustering protocols have been proposed for this. In this extensive survey, we have analyzed various cluster based routing techniques. The techniques used for CH selection in various protocols are also highlighted. The comparative table having authors name, year of publishing, advantages and disadvantages of various CH selection protocol are also described in this paper.

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