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Cluster Based Routing Protocols for Higher Energy Efficacy in WSN

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Abstract

Wireless Sensor Networks is replacing the conventional networks everywhere because of its ease of implementation, maintenance and low cost. But one of the major constraints which needs to be considered while designing a WSN is efficient use of energy to route data as the energy available to the nodes is limited. Hence, a lot of research has been done to develop efficient routing techniques and clustering is one of them. This paper focuses on the three widely used clustering techniques that are used for data dissemination.

1. INTRODUCTION

A WSN has many sensor nodes to sense the physical characteristics around them and usually these nodes are deployed in harsh conditions. Initially WSN was developed for military purposes like battle field surveillance, establish secure communication behind enemy lines etc. But now-a-days the scope has widened and it is used even in health monitoring. To meet those growing developments, there was a need to develop energy efficient method to implement WSN. This led to the creation of widely popular clustering algorithms.[1][2]

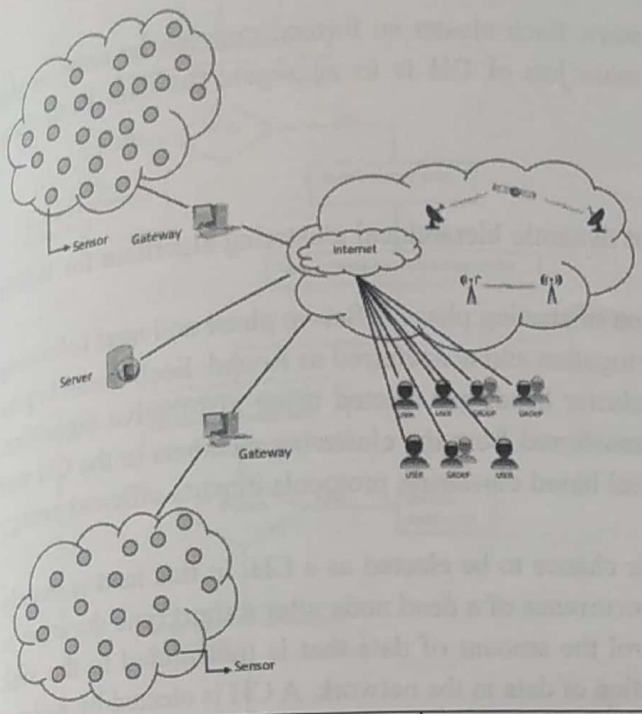

Fig. 1 Architecture of WSN

In a clustering algorithm, a large network of nodes is divided into clusters and each cluster has a cluster head. All the intra-cluster communications among various clusters are performed by the cluster heads and thus every node does not participate in all the communications which saves a lot of energy. Since selection of CHs is pivotal in deciding the energy proficiency of the entire system. So, the clustering algorithms that are discussed in this paper are primarily concerned with selecting the best CH that prolongs the lifetime of the cluster by conserving energy.[3]

CHARACTERIS-TICS	WIRED NET-WORK	AD-HOC NET-WORK	WSN
DEVICE SIZE	Medium to Large	Small	Small
DEPLOYMENT SCALE	Less dense	Scattered	Dense
COST	High	Low	Low
EFFCIENCY	Medium	Medium	High
MOBILITY	Low	High	Medium
FLEXIBILITY	Low	High	High
COMMUNICA-TION MODE	Point to point	Point to point	Broadcast
AGGREGATION/FUSION	Possible	Not suitable	Possible
SECURITY	High	Low to Medium	Low to Medium
NATURE OF NETWORK	Static	Dynamic	Dynamic

Table 1. Comparison of various networks

1.2 Purpose of Clustering Algorithms

For effective vehicular communication, there are many factors that are needed to be kept in mind. These include fault tolerance, programmability, maintainability, quality of service and many more. But for efficient routing the most important factor is energy consumption. Life expectancy of a network depends majorly on the efficiency of energy. Clustering concept in hierarchical protocol stipulates a number of pros over other conventional routing protocols [4].

Clustering protocols are the most suitable protocols among the others. This technique provides elevated scalability, reuse of bandwidth, decreases the transparency in communication, improves resource sharing, provides inter and intra cluster formation, increases the packet delivery ratio and reduces communication overhead [5]. This is a systematic technique for unstructured networks and because of all these reasons this technique is highly apposite for routing in Wireless Sensor Network (WSN).

In WSN, all the nodes are divided into a number of clusters. Each cluster so formed may not be same as the previous one and is having a cluster head (CH). The main job of CH is to aggregate the data from their surrounding intra-clustering nodes and pass it to the RSU.

2. Low-Energy Adaptive Clustering Hierarchy(Leach)

LEACH is the first and most popular used energy efficient dynamic hierarchical clustering algorithm for WSNs that was advised for better energy utilization [7].

The operation of LEACH is bifurcated into two phases. First or starting phase is Set-up phase and next following phase is Steady-state phase. Both the phases are combined together and are referred as Round. Each round begins with a set-up phasein which the clusters are chosen and cluster heads are elected using distributive algorithm, followed by a steady-state phase in which information is transferred from the clustering members to the CH and onto the base station or RSU or another cluster. Hierarchical based clustering protocols imparts efficient energy consumption because of its clustering architecture.

The main purpose of LEACH is that every node gets a fair chance to be elected as a CH. In this load is evenly distributed by CH role rotation [8]. So, the probability of occurrence of a dead node after a short time duration is reduced to almost zero. Also, clustering architecture control the amount of data that is transmitted to the sink through CH and even increases the scalability of dissemination of data in the network. A CH is elected by using a threshold value. This term is determined by using a number of factors. This includes

-r, current round number

-p, desired percentage of CH nodes and

-G, set of nodes that have not been elected as CHs in last (1/p) rounds [9].

All the cluster member nodes that are not CHs only communicate with the CH in TDMA fashion. They do so using the minimum energy needed to reach the CH. Also, to minimize the interference between clusters, LEACH uses CDMA technique.

2.1 Leach Working

Generate a random number, Rn having a value between 0 and 1 for each node in the network. Each node's Rn is compared with threshold value, Tn. Nodes having Rn<Tn becomes cluster heads, CHs and remaining nodes are just cluster nodes/members for that round. Each elected CH signal a message to all other nodes. Based on the strength of received message, the cluster members decide whether to join cluster or not. If they are interested in joining the cluster, they send a request join message to respective CH. Whenever there occurs a tie in CH selection, node degree or average distance to neighboring parameters is used. Based on the number of nodes connected, the CH will accept or reject the request made. After the formation of the cluster, the cluster members then send apprehended or sensed information to their own CH. The CHs then convey the aggregated and refined information to the sink (RSU or Cluster). When the allocated time gets over, the set-up phase starts again [10].

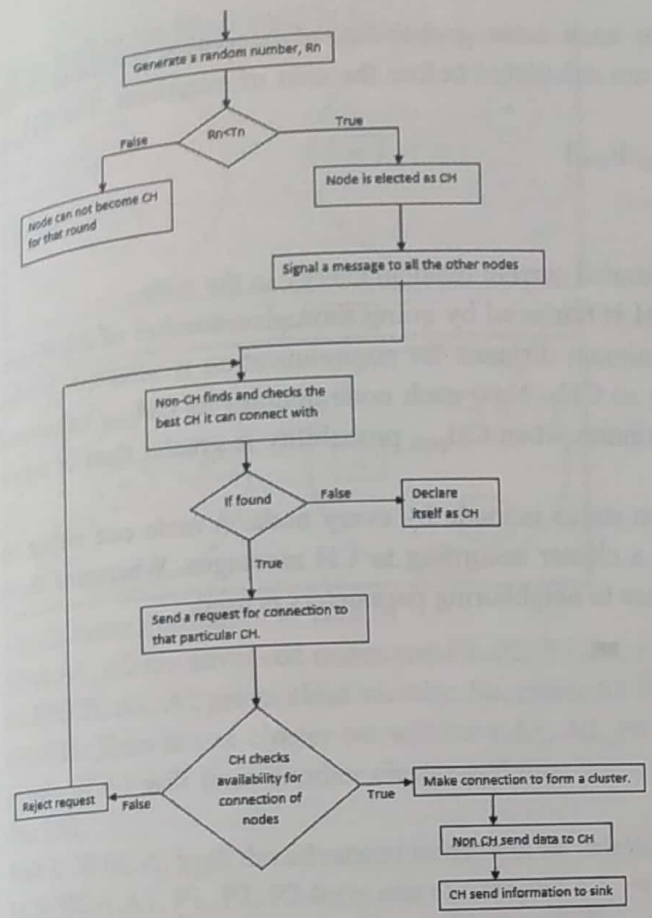

Fig.2 Cluster Formation in LEACH

Therefore, the time complexity of LEACH protocol is constant and node mobility is limited.
Despite being a trademark protocol, LEACH also has certain challenges and weak spots. CH distribution may not always be suitable and helpful. Therefore, LEACH is somewhat unreliable. Also, it is a one-hop inter-clustering technique which means that it is not desirable and apt for large sized networks. CH are selected on the basis of random number i.e., on the basis of a probabilistic term, therefore, it may be possible that CH are selected that are close to each other.
Several protocols are proposed and designed and most of them are variants of LEACH protocol with minor changes, improvement and enhancement.[6]

3. Hybrid Energy Efficient Distributed Clustering (HEED)

In order to prevent CH from completely depleting network and get fast convergence time, another more reliable, consistent and trustworthy approach is used. HEED is one such technique which selects CH in a constant number of iterations to form a uniformly distributed CH network. In a short time period, this protocol became a widely-used protocol. By evenly apportioning the power consumption, HEED has lengthened the lifetime of the network. HEED does not select the CH in a random fashion but based on some local information it completes this operation. This clustering produces similar shaped clusters by uniformly spreading the CHs throughout the network. This in turn increases the scalability and robustness of the network.
HEED is a distributive clustering scheme which considers two parameters for selecting CH. These include residual energy and cost of communication within the intra-cluster. HEED is partitioned into three phases[11]. These include-

Initialization Phase: In HEED clustering protocol, for each node probability of becoming a cluster head (CH_{prob}) iscalculated in every iteration. The probabilities are calculated before the start of execution. The CH_{prob} value is calculated using formula as

$$CH_{prob}=C_{prob}*(E_{res}/E_{max})$$

where,

E_{max}=Maximum energy

C_{prob}=Initial percentage of CHs among all nodes E_{res}=Estimated current residual energy in the node

Repetition Phase: In this phase, the most appropriate CH is retrieved by going through a number of iterations. CH having the highest residual energy and requiring minimum distance for communication is selected. Nodes that are not covered by any other node elects themselves as CHs. Now each node doubles its CH_{prob} value and goes to the next iteration of this phase. The iteration terminates when CH_{prob} probability is greater than or equal to one.

Finalization Phase: In this last phase, a final decision on status is made by every node. A node can either be selected to become a CH according to its CH_{prob} or join a cluster according to CH messages. Whenever there occurs a tie in CH selection, node degree or average distance to neighboring parameters is used.

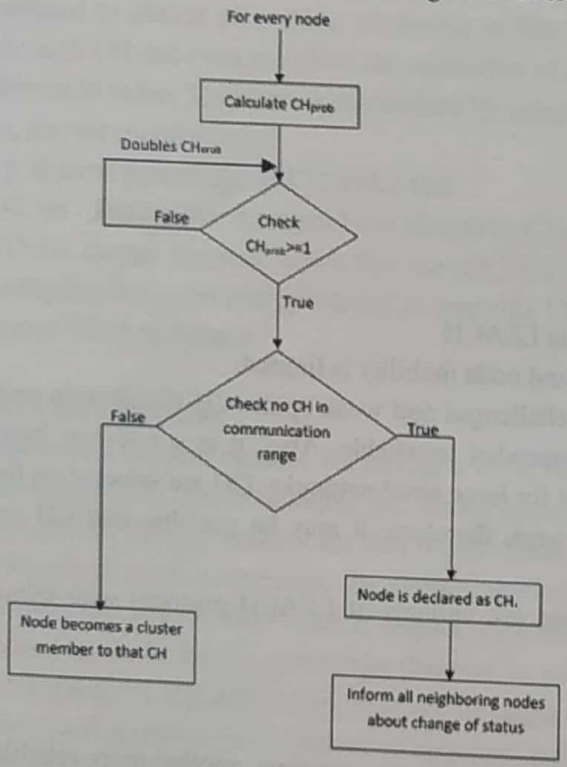

Fig.3 Cluster Formation in HEED

HEED saves energy by distributing load but sometimes it elects extra CH. It involves significant localized overhead in each iteration. And since a lot of iterations are required to make clusters, therefore, a large bandwidth is consumed. It has limited node mobility and does not support multilevel structure [8].

4. Weight Based Clustering Algorithm (WBCA)

One of the major problems encountered with HEED was that it did not guarantee selection of Advanced Nodes (High Energy Nodes) as CH every time.

For e.g., if two Advanced nodes are in close vicinity to each other then only one of them is chosen as the cluster head and this may sometimes lead to selection of plain nodes as CH.

If we look at the Fig.5 and Fig.6

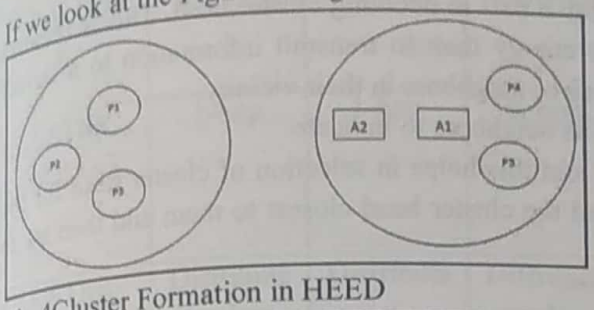

Fig.4Cluster Formation in HEED

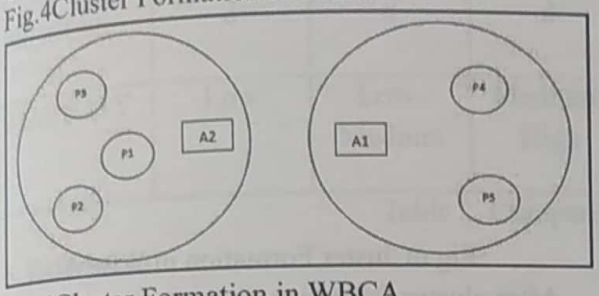

Fig.5Cluster Formation in WBCA

Here A1, A2 are advanced nodes and P1, P2, P3, P4, P5 are plain nodes.

In HEED, A1, A2 are in close vicinity. So, either A1 or A2 is selected as the CH. Let us assume that A2 becomes the CH. Then in one cluster we will have A1, A2, P4 and P5, whereas P1, P2, P3 which are not in transmission range of A2 will form another cluster and thus one of the plain nodes among P1, P2 or P3 will have to become the CH.

But in WBCA, both the advanced nodes can be selected as CH and so the selection plain nodes as CH is reduced.

In WBCA,A1, P1, P2, P3 form one cluster and A2, P4, P5 forms the other cluster.

In WBCA, energy of a node is compared with the average energy of the system, and all those nodes that have energy greater than the average energy of the system can become the cluster head.The only exception to the above rule comes if the energy of the node after becoming cluster head becomes less than the energy of the plain nodes. Thus, if two nodes have sufficient energy then they both can become CH, irrespective of their close vicinity to each other [12].

4.1 WBCA Working

In WBCA following factors are considered to decide a CH.

i.) Residual Energy: During various data transmission node losses energy and the left over energy after each transmission is called as residual energy. If a node has small residual energy as compared to other nodes then its energy consumption is large and is unsuitable to become a CH because a CH has to handle more load than the other nodes and if CH has low residual energy it will die quickly and the system will become unstable. Thus, those nodes are preferred that have high residual energy.

This helps to increase the longevity of the cluster.

ii.)Cluster Head Time or Cumulative Time [13]: Cluster Head Time (CT) tells the amount of timespent by that node as cluster head.

If a node has high cumulative time then it is not preferred, because CH has more load and if a node has high CT it means it is losing energy at a faster rate than other nodes. Thus, probability of that losing its energy and dying increases.

So, to distribute the load of CH evenly those nodes are preferred which have less CT.

This helps to distribute the weight of CH evenly among all the advanced nodes.

iii.) Number of direct nodes or neighbors that are alive also play a part in deciding cluster head. This is because transmitting information to a nearby neighbor consumes less energy than to transmit information to a far-off node. Thus, those nodes are preferred as CH which have more alive neighbors in their vicinity.

iv.) After each round every alive node broadcasts a message to its neighbors to indicate that it is alive. Also, each node broadcasts its residual energy and this helps in selection of cluster head for the next round. After a cluster head is selected the plain nodes find the cluster head closest to them and then try to become their child and various clusters are formed [12].

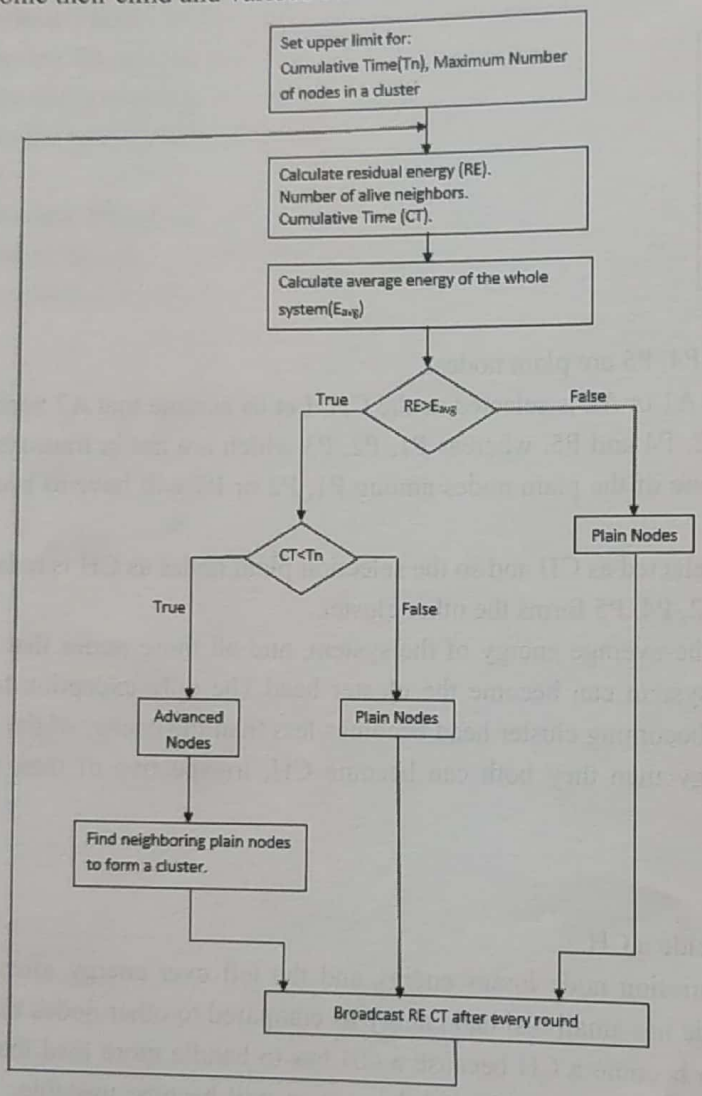

Fig.6Cluster Formation in WBCA

After cluster formation, inter-cluster and intra-cluster communication takes place and for intra-cluster communication Time Division Multiplexing(TDMA) is used for transmission .Thus, only one node can send information to the CH for a particular Time period.

4.2 ADVANTAGES OF WBCA

i.) This algorithm works in heterogeneous environment as well whereas in leach and heed we have to assume that the environment is homogeneous.

ii.) In WBCA cluster heads are dynamically selected on the basis of their energy position and cumulative time. Thus, the lifetime of entire cluster increases as the load is shared among various nodes.

iii.) Since CH are selected on the basis of their energy so the probability of selecting a plain node as Cluster Head also reduces significantly.

iv.) Since the selection of CH is dynamic so the cluster can adjust itself to the changing conditions.

5. Conclusion

In this paper, we have discussed three major clustering algorithms along with their advantages and disadvantages. Since even distribution of load and efficient consumption of energy are paramount for network stability, we came to the conclusion that WBCA is better than HEED and LEACH.

The main advantage of WBCA is that probability of selection of advanced node as CH is much better as compared to LEACH and HEED.

PARAMETERS	LEACH	HEED	WBCA
CLUSTER TOPOLOGY	1-hop	1-hop	K hop
CLUSTER PROCESS	Distributed	Distributed	Distributed
STABILITY	Low	Low-Medium	Medium-High

Table 2. Comparison of LEACH,HEED,WBCA

6. References

[1] Monika Gautam, Vikas Sejwar ,"A Brief Review Of WSN Energy And Routing Protocols",*International conference on I-SMAC*, I-SMAC 2017

[2] S.Dhiviya, A Sariga, P.Sujatha, "Survey of WSN using Clustering" *Second International conference on Recent Trends And Challenges in Computational Models*, 2017

[3] S.B. Kaebeh Yaeghoobi, M.K. Soni, S.S. Tyagi "Performance Analysis Of Energy Efficient Clustering Protocols to maximize WSN Lifetime"*International conference on Soft Computing Techniques And Implementation, YEAR* 2015

[4]Prakashgoud Patil, Umkant Kulkarni N.H.Ayachit "Some Issues in Clustering Algorithms For Wireless Sensor Networks",*IJCA Special Issue on SecondNational Conference-Computing, Communication and Sensor Network* ,2011

[5] Sagar Gouda,S.Patil, Anand Gudnavar, K.Chandan "Energy Efficient and Reliable Routing in Densely Distributed WSN" *Communication Systems, Computing and IT Applications (CSCITA)*,April 2017

[6]Konda Hari Krishna ,Tapas Kumar ,Y.Suresh Babu "Energy Effectiveness Practices in WSN over simulation and analysis of S-MAC and leach using the network simulator NS2*" International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)"*, 2017

[7] S Taruna, Sakshi Shringi, "A Cluster Based Routing Protocol for Prolonging Network Lifetime in Heterogeneous Wireless Sensor Networks", *International Journal of Advanced Research in Computer Science in Software Engineering*, vol 3, issue 4,April 2013.

[8] Mamta, "Various Clustering Techniques in Wireless Sensor Networks", *International Journal of Computer Applications Technology and Research*, vol 3- Issue 6, 381-384, 2014.

[9] Harpinder Kaur, Navjot Kaur, Sandeep Waraich, "Comparative Analysis of Clustering Protocols for Wireless Sensor Networks", *International Journal of Computer Applications*, vol 115-No.1, April 2015.

[10] N. Thangadurai, R.Dhanasekaran,"Energy Efficient Cluster Based Routing Protocol for Wireless Sensor Networks", *International Journal of Computer Applications*, vol71-No.7,May 2013.

[11] Karthik N V, Dr. Suresha,"Enhancing the Performance of Heed Clustering Algorithm for Wireless Sensor Network using Artificial Intelligence",*International Journal of Research In Science and Engineering.*

[12] Ravi Tandon, BiswanathDey, Sukumar Nandi, "Weight Based Clustering in Wireless Sensor Networks", *Communications (NCC), National Conference*, Feb 2013.

[13] Babu.N.V, Boregowda S B, Puttamadappa C, Shivaraj.S.Davanakatti, " An Optimized Weight Based Clustering Algorithm in Heterogeneous Wireless Sensor Networks", *ICAITA*, pp. 185-195, 2012.