Journal of Engineering and Applied Sciences 12 (Special Issue 12): 9566-9571, 2017
ISSN: 1816-949X

A Review on Energy Efficient Clustering Algorithms for Wireless Sensor Network

Lalit Kumar Vishwakarma and Manish Pandey
Department of Computer Science and Engineering,
Maulana Azad National Institute of Technology (MANIT), 46200 Bhopal, India

Abstract: In the 21st century, sensor system turns into a key range for exploration and development. Remote sensor nodes are employed as a part of numerous territories like farming, military, medicinal services and debacle administration and so on. Nowaday, it is finishing up exceptionally valuable for media transmission and system industry. In the remote sensor systems, sensor hubs, detects the physical condition and detected information is sent to the base-station. Sensor nodes are deployed on a geographical area where human intervention is not possible or very difficult. The researchers are using the clustering technique for enhancing the lifespan of wireless sensor network. The clustering is providing the solution for problem of hot-spot and is also used for balancing the load and scalability of the network. In recent times, various clustering algorithms are given by researchers for improving the lifespan of the sensor systems.

Key words: Clustering techniques, Wireless Sensor Network (WSN), energy, efficiency, increasing, lifespan

INTRODUCTION

A network made of the tiny sensor nodes is called Wireless Sensor Network (WSN). A sensor node is an autonomous device which senses the phenomena from its surrounding environment and transmits the information to the base-station after aggregation and fusion of the collected data. A sensor node consists of a battery, a sensing unit, a memory unit for storing the collected data and a communication unit. Initially the WSN was invented for the military applications but presently it is also useful for many areas like agriculture, industrial and health monitoring, etc. (Daramola *et al*., 2008).

Key challenges in WSN

Energy efficiency problem: In WSN the sensor nodes deployed in in physical harsh environment where a human access is not possible for the better management of network and where the battery of the sensors can't be changed. There is the need of better utilization of the energy for prolonging network lifetime of WSN (Fig. 1).

Hot-spot problem: When the sensors forward data sensed by them to the base-station using multi-hop then the nodes near to the base-station comes in use more frequently than other nodes, so, the energy consumption of these nodes will be more and due to this they will die soon.

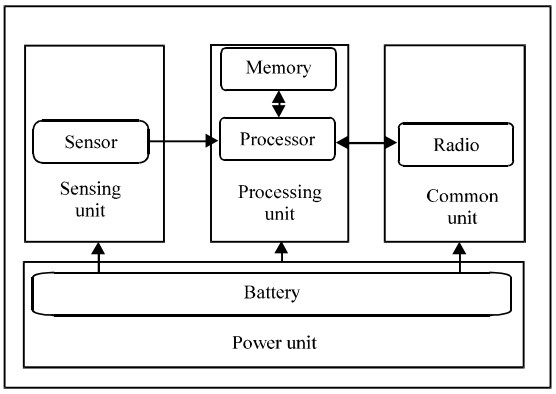

Fig. 1: Architecture diagram of sensor node (https://www.slideshare.net/BillSimpson2/ns2-41443451)

Load balancing and scalability of the network: The scalability property satisfied by WSN when the new sensor units are easily added to the network. The balancing of the load in the network is the distribution of the load of a sensor node among other sensor nodes. The clustering technique is adopted by the researchers for efficient utilization of energy. Some of the above challenges are overcome as:

Clustering: it is the grouping of same type of objects. The researchers applying clustering for efficient consumption of energy for WSN's. The network is

Corresponding Author: Lalit Kumar Vishwakarma, Department of Computer Science and Engineering,
Maulana Azad National Institute of Technology (MANIT), 46200 Bhopal, India

divided into a certain number of clusters. Each cluster (sub-network) has its own leader which is called as cluster-head. In two level hierarchy, sensed data is send to CH by the cluster members. The cluster-head perform fusion, data aggregation on collected data and then the information is sent to the base-station either through directly and/or through the intermediate communication with other cluster-heads. There are some benefits of clustering, the routing table size decreases, the energy utilization increases.

Clustering parameters: Clustering parameters are used for two things, first is the comparison of clustering protocols and second is the categorization of the clustering protocols.

Role and type of the node: In network model, the cluster-heads have resources and energy than other nodes called as heterogeneous WSN. There are 2-4 levels heterogeneous architecture. The network in which every sensor node are equal in capabilities are called as homogeneous WSN.

Cluster-head selection: In some algorithms, cluster-heads can be preassigned are classified in static head selection algorithms. In homogeneous WSN when the cluster-heads are selected from the nodes based on probability or other more specific criteria like residual energy, are classified in dynamic head selection algorithms.

Hierarchical clustering: In the first-level hierarchy the sensed data is sent to cluster-head from member nodes. Then the cluster-heads form the second-level hierarchy. In second-level hierarchy cluster-heads forward the information to base-station using another cluster-head as intermediate node. In recent years, various clustering algorithms has been introduced for better utilization of energy. Algorithms for clustering can be classified by considering infrastructure of the network, sensor node types used and data transmission either by using direct or by using intermediate nodes (Fig. 2).

Literature review: The WSNs clustering algorithms can be classified as homogeneous and heterogeneous clustering algorithms (Culler *et al*., 2004; Martincic and Schwiebert, 2005). In homogeneous WSN all the nodes have equal battery power and hardware capabilities. In heterogeneous WSN, sensors nodes which are having different communication range, sensing range (Sasikumar and Anitha, 2014). The heterogeneous WSN also considers energy for defining a network as heterogeneous, if a WSN have two

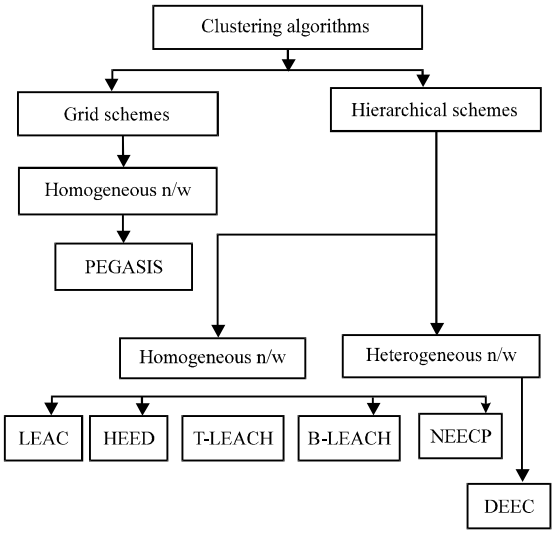

Fig. 2: Hierarchical diagram of clustering algorithms

kinds of nodes, one kind of nodes have more energy than other nodes, it is known as 2-level Heterogeneous WSN.

Clustering techniques for homogeneous WSN

LEACH (Low Energy Adaptive Clustering Hierarchy): LEACH was first and one of the most popular hierarchical clustering protocol. LEACH is a distributed, homogeneous, clustering algorithm based on probability (Yadav and Sunitha, 2014; Nayak, 2014). In LEACH, data is forwarded from members nodes to cluster-heads using TDMA and then cluster-head sends the data to the base-station.

In LEACH algorithm, whole operation is divided into number of rounds. Every round contains two phases, first is setup phase then second is the data transmission phase. In the setup phase, formation of clusters is done. For forming clusters, first selection of the cluster-head is done and then selection of the respective cluster members is done. For selecting the cluster-head, cluster nodes calculate a threshold value which is based on probability. A number is randomly generated between 0 and 1 by the cluster node. If the random numbers that are being generated by the sensor node is less than the threshold strength of signal then the respective node can now become the cluster-head. The Threshold value for sensors is calculated as:

$$T(N)=\begin{cases}\dfrac{p}{1-p\left(r \bmod \dfrac{1}{p}\right)} & \text{if } n\in G\\ 0 & \text{otherwise}\end{cases}$$

Where:

G = The set of sensors that are involved in the cluster-head election

P = The fraction of sensors that will become cluster-head. Initially in LEACH, the value of P is 5%

r = The current round

MATERIALS AND METHODS

Cluster formation algorithm for LEACH: Cluster-heads broadcasts advertisement message using CSMA MAC protocol. Each node determines its cluster-head for this round, based on the signal strength of advertisement message. Each non-CH node sends join request to its chosen cluster-head. Chs set the TDMA schedule for communicating with its non-cluster nodes of its cluster.

In steady state phase, the cluster-head collects the sensed information from the member nodes using TDMA. The cluster-head aggregates and fuses the information and sends it to the BS.

In clustering, sensed data is received by the cluster-head and then cluster-head sends it to base-station which is far from the cluster-head. The energy consumption for sending information of cluster-heads is greater as compare to cluster members. In LEACH, for better utilization of the energy the job of cluster-head is rotated b/w the nodes so the energy consumption decreases. In LEACH, the network is clustered into small sub WSN, so, the new sensors can be easily added in the network, the scalability is also improved in LEACH. LEACH does not provide solution for the hot-spot problem.

PEGASIS (Power-Efficient Gathering in Sensor Information System): PEGASIS is an advancement to the LEACH algorithm. PEGASIS algorithm focused on data gathering and gives the idea that network lifetime can be increase without forming clusters (Lindsey and Raghavenda, 2002).

In this algorithm, a chain is established from farthest node to nearest node to BS. Each sensor sense data and merge it with received data and then it will forward the data to its neighbor. The neighbor sensor node is near to base-station. Finally, the node nearest to the base-station will send that processed information to base-station.

PEGASIS outperforms than LEACH as it eliminates the requirement of forming dynamic clusters so overhead of forming cluster is reduces, energy is utilized. PEGASIS is provide load balancing as fusion is done at each sensor node rather than creating overhead at a single node, so that, all nodes will die nearly at the same time. The forwarding of received data by sensor nodes nearer to the base-station which is overhead. The nodes nearer to base-station will die soon. The PEGASIS does not provides better solution to hot-spot problem.

HEED (Hybrid Energy-Efficient Distributed clustering): HEED is very popular clustering algorithm. In HEED, data from sensors to cluster-head sends using single-hop communication and Multi-hop communication is used b/w cluster-heads and base-station (Younis and Fahmy, 2004; Chand *et al*., 2014). Based on two parameters HEED choses the cluster-heads, parameters are communication cost and residual energy. Residual energy parameter is used to choose the set of cluster-heads initially based on probability. In HEED, each node is come under only one cluster and can directly communicate to cluster-head.

At the beginning, the algorithm sets an initial number of cluster-heads is called C_{prob}. Each sensor calculate probability to become cluster-head, CH_{prob} as follows:

$$CH_{prob} = C_{prob} \times \frac{E_{residual}}{E_{max}}$$

Where:

$E_{residual}$ = Residual energy

E_{max} = Maximum energy which corresponds to a fully charged battery

The cluster-head selection algorithm starts with each sensor node setting its initial probability to becoming the cluster-head. Now the main function of the HEED algorithm will start execution. Initially the nodes which are selected to become the cluster-head will be declares as tentative cluster-head and advertisement (request) massage will be transmitted to neighbors. The execution will be terminated when sensor node will get an advertisement (request) message from its neighbor and it will change its status to 'covered'. If sensor does not get any advertisement message till completion of iteration. Then it doubles its probability and again start the execution of the main function. The sensor will repeat either he will receive an advertisement (request) message or its probability reaches to 1. If its probability reaches to 1 then it will announce the advertisement massage to become cluster-head to its neighbors. This algorithm will terminated in O(1).

The HEED algorithm uses intra-cluster communication cost and residual energy as primary parameters for clustering. The lifetime of network increases. In HEED algorithm, the node degree is used for load balancing. For distributing the load, the higher degree nodes are selected as cluster-head. The HEED is clustering algorithm so the WSN is scalable. The HEED does not solve hot-spot problem.

T-LEACH (Threshold-based LEACH protocol): The T-LEACH is the extension of the LEACH. In T-LEACH the cluster will not get replaced till the CH maintain his residual energy level above Threshold energy level. We will replace the CH by the time threshold value is greater than residual energy (Hong *et al*., 2009).

In LEACH algorithm, the whole operation is divided into two phases, one is the selection of cluster-head periodically and second is the receiving and sending of data in each round which is an overhead to network and decreases lifetime of network. The threshold value calculated as:

$$P_{Th} = Count_{RND} \times (pk_{Tx} + pk_{Rx}) P_{Tx}$$

Where:

P_{Th} = The Threshold value
$COUNT_{RND}$ = Number of round can be performed
Pk_{Tx} and pk_{Rx} = The data size which has to transmit and receive, respectively
P_{tx} = Amount of consumption in energy for transmitting or receiving 1 bit

T-LEACH provides better energy utilization than LEACH because it is reducing the overhead for replacement of the cluster-head for a while. In this calculation, the system is separated into groups so that the span of the steering tables of the hubs will be less. So, the new sensor hubs can be effectively added to the system effortlessly with less overhead. T-LEACH does not give a decent answer for the problem area issue.

BLEACH (location based balanced clustering algorithm for WSN): In BLEACH algorithm, huge energy is spared by distributing the cluster in even manner and decreasing number of control packets (Goyal *et al*., 2016).

In BLEACH routing protocol sensor node will send or receive the control packets when sensor node will change the state. In BLEACH routing protocol following states are considered for control packets and every control packet will carry different information. The control packets are generated when sensor node changes state as:

- Sensor node to cluster-head node
- CH removal
- Sensor node joining the cluster
- Sensor node leaving the cluster

In BLEACH, cluster-heads are selected on facevalue of a sensor node. The sensor whose facevalue is larger will become the cluster-head. The facevalue of a sensor node is calculated as follow:

$$S(i).fvalue = (N + (D_{max} - S(i).d + S(i).P))^{(S(i)E - Eavg)}$$

Where:

S (i). f value = Face value of sensor i
N = Number of alive nodes in neighbor/number of alive nodes
D_{MAX} = Maximum distance b/w base-station to node
S(i).d = Distance b/w node and base-station
S(i).P = Number of rounds that node become non-CH
S(i).E = Remaining energy of node
E_{avg} = Neighbor node's average Energy

Algorithm for find the number of CHs required in the wireless sensor network in BLEACH:

1. Calculate alive sensors in WSN
2. For each alive node repeat the following 3 and 4 steps
3. If number of clusters are zero then find the node with maximum face value and with minimum neighbor nodes and make it cluster-head
4. If distance (n) greater than or equal to threshold distance and energy of sensor is greater than the threshold energy level, assign that as cluster-head and execute 5-7
5. If neighbor nodes greater than threshold limit then find the node in cluster with next best and divide the cluster in two clusters
6. Compare cluster-head with all the cluster nodes
7. If associated value (n) greater than associated value of cluster-head and distance less than threshold limit then change cluster-head with that node

BLEACH gives effective usage of the vitality of WSN by diminishing the quantity of control bundles to be sent in the system and clustered the WSN into groups in significantly effective way. The BLEACH protocol gives stack adjusting by ascertaining the quantity of cluster-heads required and by finding the ideal hub that can be the cluster-head. BLEACH does not give a superior answer for the problem of hot-spot in the WSN.

NEECP (Novel Energy-Efficient Protocol for Prolonging Lifetime of WSN): A novel grouping component presented with customizable detecting range for cluster-heads determination presented by Singh *et al*. (2016). The adjustable detecting range is dependent on three parameters, the distance b/w farthest node from base-station, distance b/w the closest node from the

base-station and third parameter is the maximum sensing range of the nodes which is a constant. This clustering protocol solves the hot-spot problem.

In NEECP, two phases are there in a round. The first phase is CH selection in which cluster-head is selected on the basis of four parameters, sensors initial energy, residual energy, number of sensors in the detecting range and the total no. of nodes in the n/w.

The head selected by random number generating the number from 0 and 1. If random number is less than threshold value then node can become the CH. We can get threshold value as:

$$T(N) = \frac{p_{opt}}{1-p_{opt}\left(r \bmod \left(\frac{1}{p_{opt}}\right)\right)} \times \frac{E_{residual}}{E_{initial}} \times \left(\frac{D_n}{N}\right)$$

Where:

p_{opt} = Initially required number of cluster-head
$E_{residual}$ and E_{inital} = Initial and residual energy of sensors
D_n = The number of nodes are in the sensing range and N is total sensor nodes in the WSN

NEECP uses adjustable sensing for solving the area blank (hot-spot) problem. The adjustable sensing range is calculated as:

$$R_{CH} = \left(1-\left(\frac{d_{max}-d(BS, S_n)}{d_{max}-d_{min}}\right)\right)R_{max}$$

By using adjustable detecting range, the cluster-heads which are nearer to the base-station will spend moreenergy for passing the information of another clusters.

NEECP uses the chaining for transmitting data to cluster-head and multi-hop communication for transmitting from cluster-head to base-station. It has two variants, one is with aggregation and another is without aggregation. In aggregation, data is aggregated/fused. Then removal of duplicate data is performed and is sent to the neighbor node. Without aggregation, data is simply passed to neighbor node.

The NEECP protocol provides efficient utilization of the energy, better than the HEED. The NEECP algorithm has two variants which are NEECP with aggregation (NEECPWA) and NEECP without aggregation (NEECPWOA). The NEECPWOA prolongs the network lifetime as compared to HEED. NEECPWA increases lifetime of the network compared to HEED. The NEECP divides network into different size of clusters as the cluster which are closest to the base-station are of small size and the clusters which are far from the base-station are large. The energy consumed in intra-cluster communication will be less in small clusters that will be useful for inter-cluster communication. NEECP solves hot-spot problem. The NEECP uses chaining in which data fusion, aggregation is done on the intermediate nodes, it also provides load balancing.

Heterogeneous clustering protocols

DEEC: In DEEC, the cluster-head is selected based on the probability which is ratio of residual energy (Farouk *et al*., 2014; Sasikumar and Anitha, 2014). It is two-level heterogeneous WSN's model. In DEEC, cluster-head selected among the advanced nodes based on average and residual energy. In DEEC complete operation is done in rounds. When new round begins each sensor computes the average probability by the total energy. DEEC uses the following formula for the normal and advanced sensor nodes for calculating probability to become the cluster-head:

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)}, & \text{if } S_i \text{ is the normal node} \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)}, & \text{if } S_i \text{ is the adavnced node} \end{cases}$$

Above equation is used for calculating threshold value. The Threshold value will be used for choosing cluster-head.

The DEEC algorithm is an extension of LEACH for heterogeneous sensor WSN, it gives energy efficiency. It does not provide solution for hot-spot problem.

RESULTS AND DISCUSSION

The comparison of these clustering algorithms on the important parameters as energy efficiency, load balancing, hot spot problem, scalability is shown in Table 1:

- Energy efficiency: less energy consumption for providing same services
- Hot spot problem: overhead on a particular area is hot-spot problem
- Load balancing: distribution of the work of the sensor node among neighbors
- Scalability: addition of new sensor nodes

LEACH has following drawbacks, cluster-head selection is based on probability so, a sensor can be chosen as head again.

Table 1: Comparison of different clustering algorithms

Algorithms	Energy efficiency	Hot-spot problem	Load balancing	Scalability
LEACH	Low	Exist	Decent	Easy
PEGASIS	Low	Exist	Better	Medium
HEED	Medium	May exist	Good	Easy
TLEACH	High	May exist	Decent	Easy
BLEACH	High	May exist	Better	Easy
NEECP	Very high	Not exist	Better	Easy
DEEC	Medium	May exist	Good	Medium

PEGASIS has some limitations as it requires knowledge of network topology which is quite impractical in large distributed systems and also if a single node dies it will break the network which will reduce reliability.

In HEED, the cluster-head selection and uniform cluster-head distribution is done by localized communication with some overhead. The HEED outperforms LEACH.

The NEECP outperforms than HEED. Though, it has slightly more overhead than the clustering approaches because data aggregation is performed by all the nodes except farthest node but it consumes less energy as each node transmits less data to its nearest node.

CONCLUSION

Various clustering algorithm are observed in this study. Energy efficiency is big issue in WSN. Many researchers have given various approaches for reducing consumption of energy, solve hot-spot problem, provide load balancing and provide scalability to the network. Clustering is an approach which is used to provide energy utilization and better load distribution in the WSN.

In this study, brief survey on clustering algorithms for homogeneous and heterogeneous WSN and which are Used to efficiently utilize the energy. Hierarchical clustering performs re-clustering of nodes for load distribution and provides solution for hot-spot problem, the nodes of a certain area will not die earlier than other nodes.

RECOMMENDATIONS

For the future research any two or more algorithms can be hybrid together to form an algorithm. The extension of NEECP can be consider for heterogeneous WSN's.

REFERENCES

Chand, S., S. Singh and B. Kumar, 2014. Heterogeneous HEED protocol for wireless sensor WSN wireless. Pers. Commun., 77: 2117-2139.

Culler, D., D. Estrin and M. Srivastava, 2004. Guest editors introduction: Overview of sensor networks. Comput., 37: 41-49.

Daramola, J.O., V.C. Osamor and O.O. Oluwagbemi, 2008. A grid-based framework for pervasive healthcare using wireless sensor networks: A case for developing nations. Asia J. Inform. Technol., 7: 260-267.

Farouk, F., R. Rizk and F.W. Zaki, 2014. Multi-level stable and energy-efficient clustering protocol in heterogeneous wireless sensor networks. IET. Wirel. Sens. Syst., 4: 159-169.

Goyal, S., B. Jain, A. Malhotra and G. Singh, 2016. Location based-balanced clustering algorithm for wireless sensor network bleach. Proceedings of the 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), October 3-5, 2016, IEEE, Paralakhemundi, India, ISBN:978-1-5090-4621-8, pp: 711-716.

Hong, J., J. Kook, S. Lee, D. Kwon and S. Yi, 2009. T-LEACH: The method of threshold-based cluster head replacement for wireless sensor networks. Inf. Syst. Frontiers, 11: 513-521.

Lindsey, S. and C.S. Raghavendra, 2002. PEGASIS: Power-efficient gathering in sensor information systems. Proceedings of the IEEE Aerospace Conference, March 9-16, 2002, Los Angeles, CA., USA., pp: 1125-1130.

Martincic, F. and L. Schwiebert, 2005. Introduction to Wireless Sensor Networking. Vol. 1, Wiley, New York, USA., ISBN-13 978-0-471-68472-5, Pages: 527.

Nayak, P., 2014. Comparison of routing protocols in WSN using NetSim simulator: LEACH Vs LEACH-C. Intl. J. Comput. Appl., 106: 1-6.

Sasikumar, M. and D.R. Anitha, 2014. Performance evaluation of heterogeneous-HEED protocol for wireless sensor networks. Intl. J. Adv. Res. Comput. Commun. Eng., 3: 5555-5558.

Singh, S., S. Chand, R. Kumar, A. Malik and B. Kumar, 2016. NEECP: Novel energy-efficient clustering protocol for prolonging lifetime of WSNs. IET. Wirel. Sens. Syst., 6: 151-157.

Yadav, L. and C. Sunitha, 2014. Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH). Intl. J. Comput. Sci. Inf. Technol., 5: 4661-4664.

Younis, O. and S. Fahmy, 2004. HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Trans. Mobile Comput., 3: 366-379.