ISSN(Online) : 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2016

Clustering Nodes in Wireless Sensor Network: A Survey

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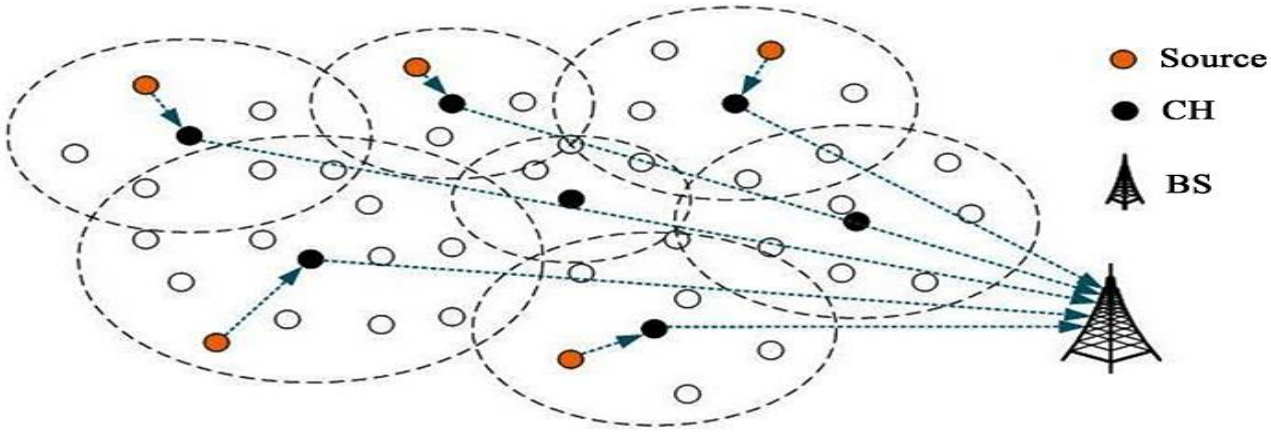
ABSTRACT: wireless sensor network is a network of spatially distributed sensor nodes used to sense the physical condition of the target environment. Sensor nodes are usually deployed in areas where manual maintenance and re-charging of batteries is not feasible. Thus nodes are organized into cluster with cluster head to make the network more energy efficient. While designing a cluster algorithm there are many design issues that should be taken into consideration. This paper provides an analysis of clustering algorithms for wireless sensor network and categorizes them on basis of cluster formation parameters.

KEYWORDS: Wireless sensor network, Energy efficient, Network Lifetime, Clustering Algorithm, Evolutionary Algorithm.

I. INTRODUCTION

Wireless sensor network is network of spatially distributed sensor nodes. They are used to sense the physical conditions of the target area and transmit the sensed data to the base station. Wireless sensor networks are have a vast range of application area. It is used in area monitoring specially in military, health care monitoring, and industrial monitoring, machine health monitoring. WSNs have hundred or even thousands of sensor nodes.



Sensor nodes have the capability to sense physical condition the target area, process and transmit information. The application of WSNs gained momentum with advancement in micro electromechanical system, low power radio frequency designs and low power digital electronics. Sensor nodes consist of microcontroller, transceivers, power source and external memory. Since sensor nodes are mostly deployed in areas where it is difficult to manually change the batteries once they go out of power. Hence, it is appropriate to make sensor nodes energy efficient. Energy efficiency is an important research area in wireless sensor network. There are works going on for manufacturing of energy- efficient sensor nodes, development of energy efficient network protocol and topology. Power is consumed by a sensor nodes sensing in processing and transmitting data. Data transmission is the most energy consuming operation in a wireless sensor network. This has motivated many researchers to develop energy efficient protocol for data transmission in wireless sensor network. Even though there is still research going on for developing low order energy radius. Most of the initial researchers assumed a first order radio model.

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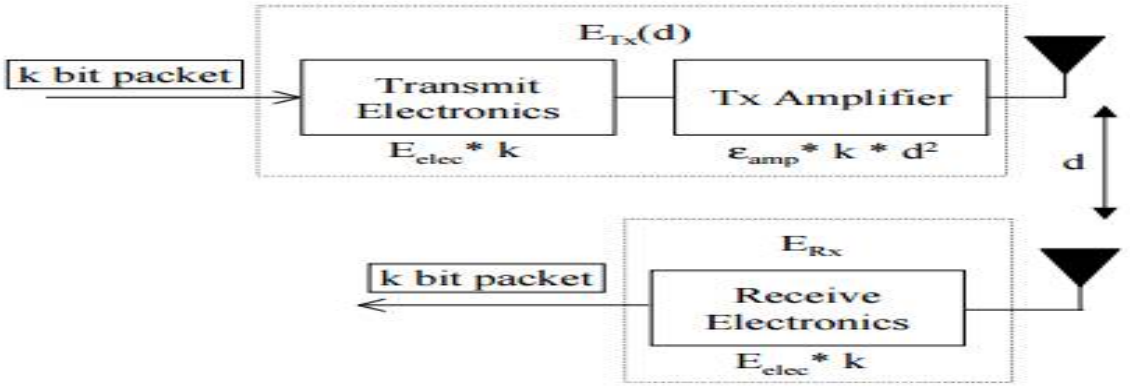

Figure 1. First order radio model

Operation	Energy Dissipated
Transmitter Electronics ($E_{Tx-elec}$) Receiver Electronics ($E_{Rx-elec}$) ($E_{Tx-elec} = E_{Rx-elec} = E_{elec}$)	50 nJ/bit
Transmit Amplifier (ϵ_{amp})	100 pJ/bit/m^2

Henzelman [1] assumed a radio transmission channel with r^2 energy loss.

$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$

$E_{Tx}(k,d) = E_{elec} * k + E_{amp} * k * d^2$

Where $E_{Tx}(k,d)$ means the energy expended for transmitting k bit message to a distance d.

$E_{Rx}(k) = E_{Rx-elec}(k)$

$E_{Rx}(k) = E_{elec} * k$

Where E_{Rx} means energy expanded in receiving a k-bit message.

If each node has to send its data directly to the base station, lots of energy will expended in transmission especially if the base station is far away. Thus an efficient approach is clustering of sensor nodes. Nodes are organized into a cluster where each cluster has a cluster head. Nodes send their data to their corresponding cluster head which then send the data to base station. Another benefit of clustering is that the data send by the member nodes could be aggregated at the cluster head, data aggregation helps in avoidance of information overload.

While designing a cluster algorithm there are many design issue that should be taken into consideration. Wireless sensor nodes have limited energy capacity and once their battery is discharged it cannot be replaced or recharged, hence the clustering algorithm should be energy efficient so as increase the network life time. Application dependency should taken into consideration as the level data aggregation may be application dependent. Even though most of the clustering algorithms are designed with energy efficiency is view, the quality of service should also be taken care of. As the quality of service is mostly an application specific requirement, it should not deteriorate below the required level. Especially in military tracking where even a small delay is unacceptable.

In this paper clustering algorithms are categorized into four groups (i) distributed clustering algorithm (ii) centralized clustering algorithm (iii) hierarchical clustering algorithm (iv) biologically inspired clustering algorithm (v) Evolutionary clustering algorithm.

II. DISTRIBUTED CLUSTERING ALGORITHM

In such algorithms, there is no centralized control; the job base station is just to receive the data send by the cluster heads. They can be used for location unaware sensor networks. The cluster organization and cluster head formation decision could be based on pre collected information about network residual energy, probability assigned to node or

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other heuristic. If any of the pre-collected information or network parameter assumptions are not accurate then the energy- efficiency could get compromised.

A. Leach Low Energy Adaptive Clustering Hierarchy LEACH [1]: This is very famous wireless sensor network clustering algorithm. The role of cluster head among nodes. This algorithm is divided into rounds. Each round consists of a cluster setup phase and a steady state phase. Each node gets a chance become a cluster head once in 1/p round where p is the desired percentage of cluster heads. Nodes that have been cluster head in round 0 cannot be re-elected as cluster head in next 1/p rounds, thus the probability of remaining nodes to become a cluster head is increased. After setup phase, comes the steady-state phase where the nodes send their data to their respective cluster head which after data aggregation send the data to the base station.

B. Hybrid Energy Efficiency Distributed Clustering (Heed):[2]

HEED was developed with the goal of prolonging the network life time. Cluster head selection in HEED is based on residual energy of nodes as the primary clustering parameter and intra-cluster communication cost as the secondary clustering parameter. The primary clustering parameter is used for probabilistic selection of the initial set of the cluster head whereas the secondary clustering parameter is use to decide which cluster head a node will join. HEED gives a uniform distribution of cluster head across the network.

C. Energy Efficiency Clustering Scheme:[3] It is similar to LEACH with some difference in cluster head selection and cluster formation. The cluster formation is based on the residual energy of nodes, when a candidate node competing for becoming cluster head finds a node with more residual energy, it gives up the competition. The base send a message to all nodes at a certain power levels so that the nodes on the basis of residual signal strength node could find approximate distance to the base station. This leads the node to select a proper communication level with the base station.

D. Threshold distributed energy efficient clustering [4]: It works on the basis of super nodes, advance nodes and normal nodes. In TDEEC the cluster head selection based on the average energy of nodes and residual energy of nodes.

$$P_i = \begin{cases} \dfrac{P_{opt}\, E_i(r)}{(1 + m.(a + mo.b))E'(r)} & for\ normal\ node \\ \dfrac{P_{opt}\,(1+a) E_i(r)}{(1 + m.(a + mo.b))E'(r)} & for\ advance\ node \\ \dfrac{P_{opt}\,(1+a) E_i(r)}{(1 + m.(a + mo.b))E'(r)} & for\ super\ node \end{cases}$$

E. Distributed energy efficient clustering:[5] In DEEC residual energy and initial are used to select cluster heads. To compute the reference energy expanded by each node during a round DEEC estimates the ideal value of network lifetime. In this protocol achieves well distributed network energy.

III. CENTRALIZED CLUSTERING ALGORITHM

LEACH-C[6] uses centralized clustering algorithm. Nodes send their energy level and current location to the base station. Based on this information base station computes the average energy of nodes. Those nodes that have their energy level below average energy level are not made cluster head. Base station now find cluster from amongst the nodes eligible to be cluster head. Finding k optimal cluster is NP-hard problem. LEACH-C does it by using simulated annealing method.

A. Base Station Controlled Dynamic Clustering Protocol:[7] BSDCP is a centralized clustering algorithm that works with multi-hop formation. The base station on receiving current energy status of nodes compute their average energy level and choose the nodes above the average energy level and choose the nodes above the average energy level to be cluster heads. The base station iteratively splits the network into sub clusters. This helps to ensure the cluster heads are uniformly distributed. The base station finds the lowest energy multi hop Cluster head to cluster head routing path and send this information to nodes.

B. Power Efficient and Adaptive Clustering Hierarchy: [8] Power efficient and adaptive clustering hierarchy for wireless sensor network. A node recognizes the destination and source of a packet by over heading a node. Peach

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works a probabilistic model and it also uses multi-level clustering. On the basis of the over head information PEACH forms cluster without the over head of advertisement, announcement, scheduling message and joining.

IV. HIERARCHIAL CLUSTERING ALGORITHM

A. Two level hierarchy for low energy adaptive clustering hierarchy (TL-LEACH):[9] By using two level hierarchy for low energy adaptive clustering hierarchy less number of nodes have to transmit large distance to transmit to the base station. This is especially useful in networks where node density is very high. There is a top level cluster-head called primary cluster head and second level cluster head called secondary cluster-head. This protocol has four phases advertisement phase, cluster set up phase, scheduled creation, data transmission. In any current round each node decides whether it wants to be primary cluster head, secondary cluster head or a simple node. The primary cluster-head send its advertisement message to other nodes and secondary cluster-head send its message to simple nodes. Secondary cluster head also send a message to advertise their primary cluster head. Simple node informs about its membership to secondary cluster head.

B. Stable Election Protocol [10]: This works in a two level hierarchy and is heterogeneous aware. The probability for a node to become cluster head is dependent on its relative initial energy. This protocol achieved a prolonged time interval before the death of first node. SEP has two kinds of nodes advance nodes and normal nodes. The advance nodes have higher chance of becoming a cluster head.

C. Energy efficient multi-level heterogeneous protocol:[11] this is a threshold based clustering method. It works with k-level hierarchy. It to achieves an improvement of 17% of SEP [10] and MCR [14] protocol. This protocol achieves prolonged network lifetime.

V. BIOLOGICAL INSPIRED CLUSTERING ALGORITHM

A. Clustering algorithm based on ANTCLUST: [12] ANTCLUST is based on swarm intelligence. It is behavior of insects like ants. It is inspired from the way the show robustness, decentralized behavior, distributed capabilities for problem solving. Here those nodes that have more residual energy become cluster heads independently. Then other nodes meet each other and through their meetings cluster are created merged and discarded. This results in the formation of energy, efficient cluster that leads to prolonged network life time.

B. Wireless sensor network clustering with artificial bee colony (WSNCABC):[13] Here sink effects cluster heads by using sensors distance from each other using artificial bee colony method. The single broadcast the information about cluster head into the network and each node on the basis of signal strength on the basis of signal strength attaches itself to closest cluster head. In the case where sink was close to the network WSNCABC performed LEACH by 70%.

VI. EVOLUTIONARY ALGORITHM

A. Hierarchical Cluster Based Routing (HCR): [15] This protocol is modified by Sajid Hussain et.al. using genetic algorithm to create energy efficient cluster for a certain number of transmission. The base station computes the complete network detail on the basis of generic algorithm and then transmits the complete network detail to nodes.

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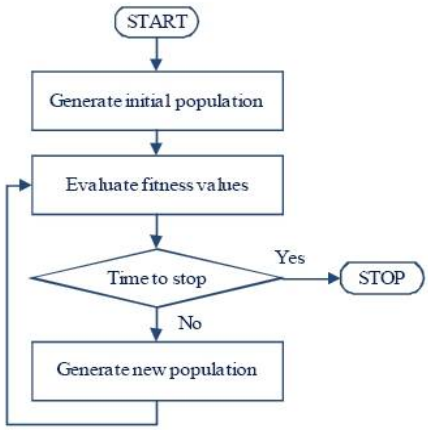

Fig.1 Genetic Algorithm

Fitness function used by

$F = \sum_i \propto (w_i, f_i)\ \forall f_i \in (C, D, E, S, T)$

Where c is cluster distance, D is direct distance to sink, E is the transfer energy, and SD is cluster distance standard deviation. T is number of transmission.

B. Clustering wireless sensor network using fuzzy logic and genetic algorithm:[16] In this algorithm each node selects its cluster head by using fuzzy module which is embedded in the node and nodes with appropriate capabilities in each area are determined. Thus fuzzy logic is used to send to the sink information related to cluster head candidates. In the sink genetic algorithm is used to determined the number and locations of cluster head.

The fitness function used

$$Fitness = \left| E^{k}_{network} - E^{k-1}_{network} \right|$$

Where E^k is cluster network energy in K^{th} period.

Hyun-Sik seo-et.al [17] used LA2D-GA. The two dimensional chromosome used in LA2D-GA has the advantage of containing location information of sensor node. The cost function used.

$$\mathrm{C_{net}} = \sum_i \sum_j d^2_{CH(i,j)} + \sum_i d^2_{SN(i)}$$

Where $\mathrm{C_{net}}$ is cost of network.

d_{CH} is transmission distance to cluster head.

d_{SN} is transmission distance to the sink.

i is the number of cluster head.

J is the number of cluster members.

Here both elitist selection and ranking selection are used.

VII. CONCLUSION

In this paper we tried to categorize clustering algorithm and provide a comprehensive analysis. Energy dissipation is the main concern is designing of wireless sensor network protocol. Energy efficiency can be increased in a verity of ways. In a clustering algorithm energy efficiency can be increased by developing better clustering algorithm. Distributed algorithms are more feasible than centralize algorithm as centralize control can incur more overhead on base station. Still centralized clustering algorithm can be helpful if base has enough resources and fast processing power. This paper describes the advantage & technique of some prominent clustering algorithm in each category. Every algorithm has its own advantage in terms of network life time, quality of service and sensing techniques. Thus which clustering algorithm to use is an application dependent decision.

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