ISSN: 2321-7782 (Online)
Volume 3, Issue 7, July 2015
International Journal of Advance Research in Computer Science and Management Studies
Research Article / Survey Paper / Case Study
Available online at: www.ijarcsms.com

Cluster Head Selection Methods in Wireless Sensor Network

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Abstract: Clustering plays a vital role in any wireless sensor network. The lifetime of the sensor node (SN) can be increased if clustering technique is being adapted in any Wireless Sensor Network (WSN). Depending on the nature of the SNs utilized in that network, the WSN may be of Homogeneous Wireless Sensor Network or it may be Heterogeneous Wireless Sensor Network. In the clustering technique, if the SNs send the information to the cluster head (CH), then the life time of the SNs further be increased. This paper deals with the various types of cluster head selection methods in WSN.

Key words: Sensor nodes(SNs), clustering, cluster head (CH), Wireless Sensor Network (WSN),

I. INTRODUCTION

The properties of the sensor network protocols can be analyzed by adopting the parameters like quality, latency, ease of deployment and system lifetime [13].The lifetime of the sensor network is limited when the environment is dynamic in nature. The reason for this is, it is difficult to recharge the battery present in the sensor node (SN) which is helpful for the operation of the SN. Genetic algorithm has been utilized in order to overcome this reduced lifetime drawback [14]. Factors influencing the network lifetime are, the node can be acting as a cluster head (CH) if the node is nearer to the cluster centroid. Generally nodes are mobile in nature. Due to these mobility criteria, the topology or routing of the network has been changed very often. This will affect the network lifetime [14].

Limitations of WSN are

- Computational power is limited
- Available bandwidth is limited
- Energy supply to the individual nodes is limited
- Limited number of wireless links that connects the SNs to the BS

The challenges faced by the WSN networks are as follows i) Quality of Service: the network should provide best QoS from the initial stage of the cluster until its final stage, ii) fault tolerance Mechanism: if there is any fault that has been occurred in the network, then immediately the fault has to be rectified. Then only it is possible for the information to be passed from one location to another. i.e. from SN to CH, then from CH to BS iii) synchronization: Proper synchronization has to be maintained between the nodes and CH and from CH to BS, iv) Cluster head selection: the purpose of the selection of the CH is to reduce the energy utilization in that network. Thereby the lifetime of the cluster has been extended. v) Construction cost: The cost for the formation of the cluster should be maintained in a proper manner.

The performance of the WSN can be analyzed with the help of energy efficiency, latency, accuracy, fault-tolerance and scalability parameters. Depending on the mobility nature of the SNs, the WSN may be of static or dynamic in nature. In the static WSN, the SNs are fixed in their location, while in the dynamic WSN, the SNs may move from one location to another

location.. Due to this mobility nature, the clustering has to be reconfigured if necessary. For this purpose the SNs, should posses self configuration characteristics [16].

Energy and power play an important role in WSN. The purpose of the clustering is to offer the needed resources that can be utilized for the operation of the WSN, there by the amount of energy consumed by the nodes is utilized in a proper manner [15].

Three methods are there to transfer the information to the base station. They are Hierarchical method of conveying information, data- centric method of conveying information and location method of conveying information. In Hierarchical method, the information has been passed in hierarchical order. i.e. the sensor nodes convey the information to the CH or secondary CH (SCH). The SCH convey the information to primary cluster head (PCH). The PCH or CH then conveys the gathered information to the base station. In location based method, the information related to the routing table or the location to be discovered and maintenance of the network has been done. In data centric method of information gathering, a query has been generated by the BS that has been conveyed to the particular area where the information is needed [17].

The purpose of deploying sensor nodes is to monitor some important parameters in that area. SN consists of a sensing element for sensing, signal conditioning element for processing the sensed parameters, transmission element for conveying the processed information either to CH or to the BS, Power supply unit for the operation of the sensor node. The purpose of using these SN s in the remote area or in hazardous area is to monitor these environments, because in those area (hazardous conditions, dense forests, deep sea etc.) it is very difficult to implement human monitoring in these areas. The SNs are operated by battery. It is not feasible to change the battery that has been attached to the SNs. To overcome this drawback an energy efficient scheme has been implemented. The rest of the paper is described as follows, section II describes about classification of wireless sensor network, section III deals with need for clustering, section IV deals with designs aspects of clustering, section V deals with cluster head determination methods, section VI provides the conclusion.

II. CLASSIFICATION OF WIRELESS SENSOR NETWORK

Wireless Sensor Networks (WSN) is collection of sensor nodes which cooperatively send sensed data to base station. These sensor nodes are operated by battery. WSN have limited computational power, limited battery power and memory power. Because of these characteristics more care has to be taken by the developer while designing a particular sensor network [2]. SNs are deployed and they measure same type of parameter (example temperature) then, the sensor nodes are said to be homogeneous sensor nodes and the network is said to be homogeneous sensor network. In h**omogeneous sensor network**, the sensor nodes have identical characteristics. i.e. sensor nodes have identical characteristics and they measures same type of parameters. For example in an area if the hardware complexity, battery power, energy level are same for all for homogeneous SNs. In h**eterogeneous sensor network**, the characteristics of the sensor nodes differ from other SN, because the SNs have to measure different parameters. So characteristics of the sensor nodes depend on the parameters they are going to measure. Hybrid sensor network is the combination of these homogeneous and heterogeneous sensor networks [7].The memory capacity of the heterogeneous SN is more when compared to the homogeneous SN. The processor present in the heterogeneous sensor node is more complex in nature. The heterogeneous SN performs well when compared to the other types of SN. The bandwidth available in the heterogeneous SN is also larger than other SNs[1]. The memory capacity of the heterogeneous SN is more when compared to the homogeneous SN. The processor present in the heterogeneous sensor node is more complex in nature. Because of these characteristics it is possible for the heterogeneous SN to perform well when compared to the other types of SN. The bandwidth available in the heterogeneous SN is also larger than other SNs [8]. In heterogeneous SNs, different SNs have different energy levels, depending on the traffic load situation, the energy distribution to the individual SN vary. This will lead to the change in the amount of energy consumed by the individual node. Because of this unknown energy consumption, the time synchronization of the individual nodes will be affected [9]. Table 1 shows to the comparison between the homogeneous and heterogeneous sensor network.

Table 1- Comparison between the Homogeneous Sensor Network and Heterogeneous Sensor Network

Homogeneous Sensor Network	Heterogeneous Sensor Network
Sensor nodes(SN) possess identical characteristics	The characteristics of the SN differs from one another
They measure same type of parameters	They measure different types of parameters
Same type of battery has been utilized for all the sensor nodes.	Size of the battery differs depending in the parameter the sensor node is going to measure,
The memory capacity of the sensor node is less	The Memory capacity of the sensor node is more
The hardware complexity of the sensor node is less	The hardware complexity of the sensor node is more.
Energy level of the SN is same for all SN.	The energy level of the sensor node differs from one SN to another SN.
Small Bandwidth	Large Bandwidth
LEACH, PEGASIS are some of the examples for Homogeneous Protocols	HEED,DEEC, DDEEC,EDDEEC,BEENISH are some of the examples of the heterogeneous protocols

Depending on the mobility of the sensor nodes as well as the Base Station (BS), the clustering can be classified into two types as static clustering and dynamic clustering. In Static clustering the SNs and BS are considered to be stationary. The selection of Cluster Head (CH) is done once. If a node is being selected as CH, then that node will act as a CH until its network lifetime. In dynamic clustering the SNs and the BS may move from one location to another, because of this mobility nature of the nodes, the CH selection occur very often depending on the situation, the CH changes[10]. The type of the network clustering used here is of static clustering

Three types of heterogeneous resources are available. They are energy heterogeneity, link heterogeneity and computational heterogeneity. Some nodes in computational heterogeneous WSN possess more memory and also the microprocessor available in those nodes is more powerful when compared to other nodes in that heterogeneous WSN. In link type heterogeneity, the available SNs are capable of covering larger distance when compared to normal nodes. In energy heterogeneity type SN, few nodes possess the compatibility of replacing the battery. The purpose of utilizing the clustering in the WSN is to reduce the amount of energy consumed by the individual node thereby extending the lifetime of the WSN [36]. Energy consumption in heterogeneous sensor network differs from one SN to another SN because the SNs perform various operations and they need different amount of energy level.

III. NEED FOR CLUSTERING

In a WSN, the nodes can be combined together to form a group called cluster. By adapting the CH selection technique, the communication between the base station and the nodes will be reduced. Thereby the power consumption or the energy utilization has been reduced. The SNs convey the information to the cluster heads in their allotted TDMA slot. Then the nodes may be in sleep mode in order to reduce the energy utilized by the individual node [16].

Two types of clustering approaches are there in WSN. They are hierarchical based approach and clustering based approach. By considering the clustering based approach, the lifetime of the network can be extended. This extension of the lifetime is an important factor in terms of the energy utilization in WSN. i.e. the life time of the WSN can be extended if less amount of energy is utilized in that network [11].

The parameters to be considered in the design of the clusters are intra-cluster communication, types of nodes (whether the nodes are homogeneous or heterogeneous) and the roles performed by them, overlapping, cluster head selection, multiple levels of clusters if the network size is large [5].

Many advantages are there by adopting clustering in a WSN [5]. They are

» It is not necessary to maintain topology information, because the sensor nodes can have contact with the particular cluster alone.

» Number of nodes participating in the transmission between nodes and BS has been reduced.

» Unnecessary message transfer between the SN has been reduced because the SNs have to convey the message or information to the CH alone.

» By implementing TDMA time schedule between the clusters, the CH convey the information to the BS at their scheduled time slot, thereby the collision of packets has been reduced.

» Due to TDMA time scheduling, the life time of the battery has been extended.

» The energy consumption of the network is reduced due to clustering.

» The scalability of the network has been expanded with the help of clustering.

Before selecting a SN to act as CH some criteria like energy consumption rate, residual energy of the SN initial energy and the average energy consumption of the network have to be considered [4]. The cluster should posses some properties like cluster count, topology between the nodes in that cluster, connectivity between the SN and CH, have to be considered. The performance measures like throughput, number of nodes per round, life time of the network, number of CH to be selected per round have to be considered. The selection of the cluster head is based on three parameters viz adaptive nature of the cluster, deterministic nature, and combined metric. In the adaptive scheme two types of categories are there. They are self organized base station and base station is assisted by others [3].

IV. Design Aspects of Clustering

The following aspects have to be considered before going to design a cluster in a WSN. They are clustering methods, cluster formation, clustering properties, capabilities of the CH, the CH selection methods.

In the clustering aspect first whether the method of clustering i.e. the centralized approach or distributed approach or the combination of the both is to be decided. After predicting the method of clustering approach, we have to decide how the cluster is going to be formed. The cluster formation may be of single hop clustering or it may be a multi-hop clustering. Then the properties of a cluster are to be decided. The properties to be considered are as follows, size of the cluster, density of the cluster, number .of messages that has to be conveyed between the CH and the SNs, the stability nature, topology within the cluster, connectivity between the CH in one cluster and the CH in some other cluster. Then the capabilities of the cluster head, the role of the CH, mobility of the CH (i.e. whether the CH is going to be stationary or it may be variable or it may be re-locatable) and nature of the node are to be decided. After deciding the capabilities of the CH, the selection of the CH has to be decided. The CH selection may be a probability based or it may be anon-probability based [12]. Figure 1 shows the flow process of the Design Aspect of the Construction of a Cluster

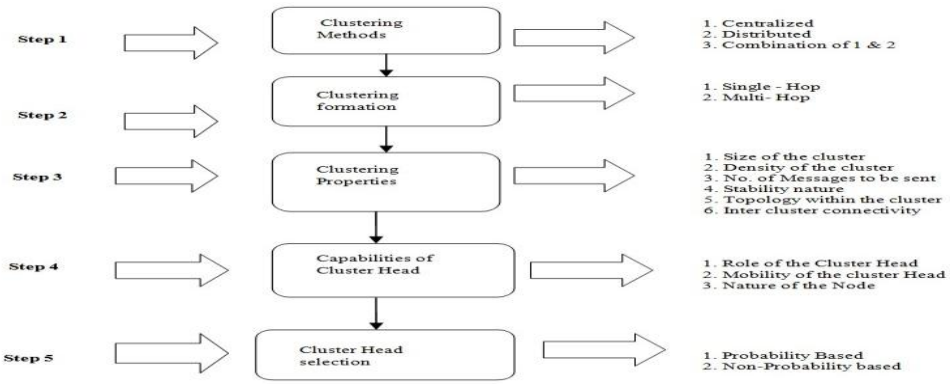

Figure 1. Flow process of design aspect of construction of cluster

V. CLUSTER HEAD SELECTRION METHODS

V.1Topology based cluster head selection scheme

The purpose of topology based cluster head selection is to identify the location of the node in that cluster. If the node is located very nearer to the partition or the border of the network, then that node may easily move to the neighborhood cluster. If the CH is located at the centre of the cluster then, whenever the CH dies, there may be a chance for the cluster to be partitioned into two. These characteristics (mobility of the node from one cluster to other, partitioning the cluster) have to be avoided. If the elected CH is failed to perform its role, then some amount of time has been consumed for re-election of the CH and to resume the clustering operation from the place where the operation has been stopped [18].

In topology based CH selection some parameters have to be considered before selecting the CH. They are position of the node, the distance between the CH and the other nodes as well as to the base station, the amount of energy that is present in that node, direction of the node, data transfer speed from node to CH and to base station. The approaches adapted to select CH may be of centralized or distributed or probabilistic or deterministic [9]. The elected CH is capable of transferring the information received from the other nodes to the base station in an efficient manner. CH is insensitive to move from one location to another, because if the CH moves then, there may be a chance of partitioning the WSN. Proper connectivity between the nodes should be created if CH fails to operate then, that information has to be reached to the other nodes immediately. Depending on the energy level, the nodes may be classified into strong node and weak node. Depending on the position or location, the nodes may be classified into border nodes and bridge nodes [18].

V.2. Coverage Preservation based Cluster head election

In probabilistic approaches the function of the CH is evenly distributed among the nodes that are present in the WSN. By doing this, the energy consumption of the nodes is distributed evenly. Therefore the lifetime of the network can be extended. The main aim for the selection of CH in WSN is, the area covered by the CH should be large. The entire cluster can be handled by the CH in an efficient manner. The purpose of implementing cluster in a WSN is to reduce the rate of data transfer from nodes to CH, then to BS. This will reduce the amount of energy consumed by the individual nodes. i.e. the node has to convey the information to the CH alone is active while other nodes may be in active mode or in sleeping mode. Interference can also be reduced by adapting clustering.

In order to elect a node to be acted as a CH some criteria has to be considered. i) Performance of the node is a vital parameter. i.e .whether the node is actively participating the group activities in the cluster or not, ii) whether the node is located at the centre of the cluster or not, iii) whether the amount of energy present in the node is sufficient enough to lead that group. Coverage time is defined as the time until one of the cluster head node runs out of energy leaving a hole the network's coverage. The average cost needed to cover a particular area has been determined with the help of coverage aware cost metrics. By adapting this strategy, the performance of the cluster head can be analyzed in an efficient manner, because the CH has to cover a wide area [19].

V.3 Cluster head election based on counting:

Consider "M**"** number of sensor nodes (SN) are in a WSN. A unique No. is given to each sensor node. The number starts from 0 to M-1. This unique no. is acting as an identifier for that SN. Assume that these sensors are combined together as cluster. Consider **"A"** no. of clusters is available in each round. Therefore we have to elect "A" no. of CHs. For each sensor "u" , an ID of u_{id} is given. These sensors have to maintain the no. of CHs created so far. This will be helpful for controlling the total no. of **CHs** in every round. As soon as the election of CH begins, each sensor has to set the no. of **CH** as 0 in the initial stage. Sensor u first increases $\mathbf{u_{id}}$ by 1 and then considers the balance $\mathbf{u_b}$ **of** $\mathbf{u_{id}}$ divide by **M** .based on the value of $\mathbf{u_b}$, the value of CH is elected.

i.e. if $u_b = 0$, then sensor u is considered to be a CH. Now this sensor u convey an advertisement message to all other SNs. While performing this advertisement message, the sensor u increments the no. of CH created by 1. This sensor node u is considered to be the CH until it is alive. As soon as the sensor node "u" dies, no advertisement message has been passed during that period. After some time, some other node is acting as CH for some other rounds

If $u_b \neq 0$, then the sensor " **u"** is considered to be an ordinary node. Now this node is ready to accept the advertisement message send by any CH. Now the sensor u increments the no. of CH created by 1.

V.4. Load based Cluster Head selection based on fuzzy Logic:

Nancy ak Bundan et al. [20] proposes a centralized cluster head selection algorithm based on fuzzy logic. The authors select three fuzzy parameters like centrality, energy and distance. According to them, the CH is being done by base station. BS selects the SN to be acting as CH with the help of "if-then" rules implemented on these three fuzzy parameters. The BS posses high storage capacity, the resource power of the BS should be in unlimited condition, then the processing power of the BS should be very high, it should be located in the middle of the sensor field, and finally the BS should be in static condition i.e. the mobility of the BS must be avoided. If these characteristics are present in the BS then, the load in the WSN should be evenly distributed. The fuzzy parameter energy has three fuzzy sub sets as low energy, medium energy and high energy, similarly the another fuzzy parameter centrality has two fuzzy sub sets like low centrality and medium centrality and the third fuzzy parameter distance has far, medium and close fuzzy sub sets. With the help of these fuzzy parameters energy x Centrality x Distance (3 x 2 x 3). It is possible to frame 18 combinations of "**if- then" rules** as the SN which posses high energy, low centrality, and medium distance then the chance for that SN to be act as CH is very high.

V.5. Fuzzy Logic based Cluster head election

The information obtained from the environment can be represented in two ways. i.e with the help of real time representation or by simulation method. In simulation method many ways are there. One such way is using fuzzy logic (FL). With the help of FL the data can be manipulated easily. By using FL the real time decisions can be easily taken even the data obtained in incomplete format.

Before implementing, the following assumptions have to be made.

1. The cluster head election should be done by the base station (BS).
2. The base station should be in static condition. i.e. it is insensitive for mobility (BS should not move from one location to another)
3. The location of the nodes has to be conveyed to the BS.
4. The channel used for propagating the information is in symmetric form.
5. The energy level of the nodes also has to be intimated to the BS. This can be done during the setup phase of the cluster formation.
6. The distance between the BS and the nodes should be large.
7. The nodes that are present in the WSN should be in homogeneous in nature (i.e nodes have identical characteristics).

The algorithm adapted in the FL scenario is similar to the centralized approach. i.e. decision has been taken by the base station alone. In order to implement this, the base station possesses more energy, power, as well as memory capacity when compared to the other nodes [21].

Mamdani method of **Fuzzy Inference System (FIS)** has been adapted here. The fuzzy logic control the model comprises of fuzzifier unit, fuzzy rules unit, fuzzy inference engine, and a defuzzyfier unit. Three main input variables like residual energy

of the node, neighbors surrounding the node, and centrality have been considered .in these main input variables, the states of the corresponding input variables have been considered for analysis purpose. In the residual energy the states like low, medium and high residual energy levels have been considered. Similarly for in No. of neighbors for that node we may have few, medium and many for centrality the three states are far, medium and close. The states of these individual input variable act as fuzzy sets. With the help of these fuzzy sets IF- THEN rules are applied in order to determine the output [22].

VI. CONCLUSION

So far we have discussed about various types of Cluster head selection methods in wireless sensor network. Selection of the cluster head is being done depending upon the situation. Before implementing the real time wireless sensor network if we determine the cluster head selection using fuzzy logic means then it is easy for us to implement the same in real time scenario.

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