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# Cluster Head Election Schemes for WSN and MANET: A Survey

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**Abstract:** Wireless Sensor Network (WSN) is an arrangement of sensor nodes to collect environmental data and send it to Base Station (BS). Mobile Adhoc Networks (MANET) is a network composed of itinerant nodes via wireless links in deficiency of any infrastructure or topology. Nodes of WSN and MANET are divided into clusters to create a temporary infrastructure for the nodes. A cluster is supervised by a leader node called Cluster Head (CH). Purpose of CH is to maintain the list of affiliated nodes and commune with other cluster heads. CH election is a vital process in cluster based networks. Many parameters can be used for electing the node as a cluster head such as location, mobility, battery, throughput etc. Numerous techniques for selecting cluster head have been proposed by researchers, focusing on parameters. We present in this paper a wide taxonomy about Cluster Head Selection method in Wireless Sensor Networks. At the end of each section we have presented a comprehensive analysis of different methods.

**Key words:** Mobile Ad-Hoc Networks · Wireless Sensor Networks · Cluster Head election · Cluster Head

## INTRODUCTION

Cluster Head (CH) election is the process to select a node within the cluster as a leader node. Cluster Head maintains the information related to its cluster. This information includes a list of nodes in the cluster and the path to every node [1].

The responsibility of the CH is to communicate with all the nodes of its own cluster. CH must be able to communicate with the nodes of other clusters. Communication with nodes of other cluster can be directly through the respective CH or through gateways. Communication is done in three steps. First of all the cluster head receives the data sent by its members, secondly it compresses the data and finally transmits the data to the base station or other CH. Suitable cluster-head can reduce energy utilization and enhances the network lifetime [3].

Electing a specific node as a cluster head is a very important but sophisticated job. Various factors can be considered for electing the best node as a cluster head [2]. Some of these factors include location of the node with respect to other nodes, mobility, energy, trust and throughput of the node.

Nodes of WSN and MANET have limited battery and resources. Process of election increases overall processing overhead of the network. So the election process must also consider the processing and energy limitations of the nodes.

One cluster head per cluster must be selected during an election process, because multiple cluster heads within a single cluster can give rise to cluster reformation, Quality of Service (QoS) and routing management issues [4].

In recent years, various surveys of CH election schemes were presented. Aim of these surveys is to discuss their parameters [4], need of re-clustering [5] and performance [6]. However to the best of our knowledge, no overview of the CH election emphasizing position of node in cluster, trust factor of nodes and single cluster head selection per election process has been discussed so far.

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In this paper, efforts have been made to discuss an extensive number of schemes proposed previously for CH election in both WSN and MANET. To have a better understanding, comparison of various CH selection techniques is made. In terms of parameters used and possibility of multiple CHs selection.

Rest of the paper is organized as follows. Section-II compares the various clustering schemes in WSN and MANET with respect to their parameters, highlighting the possibility of multiple CH selection. Section-III concludes the paper.

**CH Selection Schemes:** Cluster head election is needed in cluster based network. Much research has been done on election of cluster head in a clustering environment. Clustering is required in WSN and MANET. The previous research can be broadly categorized in *CH election in WSN* and *CH election in MANET.* In WSN Base Station can control the election process and nodes are usually not mobile, whereas in MANET, there is no central authority to control the election process and mobility is also an issue [7].

**CH Election in WSN:** Sensor nodes of Wireless Sensor Networks are controlled by Base Station. Election processes suggested by various researchers are mostly controlled by BS. Energy consumption is a major issue in WSN, therefore most of the schemes focused on energy efficiency of the nodes during election process.

A very early and classic routing protocol named LEACH (Low-Energy Adaptive Clustering Hierarchy) for wireless sensor networks was proposed [8]. In this paper, different routing protocols are discussed and their energy utilization is analyzed. Then a new technique for the selection of Cluster Head is proposed. According to this paper, every node produces a random number between **0** and **1**. If the number is less than the predefined value, the node elects itself as CHs.

Conventional LEACH protocol for energy efficiency is customized in [9]. In this paper, the authors modified the LEACH protocol to reduce the power utilization of wireless micro-sensor networks. Authors changed the LEACH's cluster head selection algorithm. In this modified scheme, the factor of remaining energy of the nodes is added in the traditional LEACH cluster Head selection equation. According to authors an increase of network duration by about 30% was obtained. Furthermore, the authors presented three new metrics First Node Dies (FND), Half of the Nodes Alive (HNA) and Last Node Dies (LND).

In [10] Gupta's Cluster Head Election using Fuzzy Logic is proposed. In this paper CH is elected using fuzzy logic. Authors used the fuzzy method called Mamdani Method [11]. Energy, density and centrality were used for fuzzy variables. The base station collects the information from every node and elects CH based on the fuzzy variables.

Another Cluster Head Election technique was proposed based on remaining energy and relative position of the node in the cluster [12]. The cluster head is selected on the basis of threshold value T. Threshold is calculated with the help of the above two factors and probability of the node. Every node generates a random number, if it is smaller than a predefined value the node elects itself as a cluster-head.

Cluster Head is selected using Analytical Hierarchy Process (AHP) algorithm in [13]. CH is elected on basis of three factors i.e., energy, mobility and distance. Different weights are assigned to three parameters and the overall weight of every sensor node is calculated. The node having largest weight is elected as cluster head.

Another effort had been made to optimize the LEACH protocol [14], in which authors develop a structure to select the probability to select a cluster head. Sleep-wakeup based solution is applied on decentralized MAC protocol. In this paper, the MAC operation is divided into rounds. In the proposed work the cluster heads stay active at all times and other nodes may sleep during the inter cluster communications to save energy.

In another solution cluster head election algorithm for WSN is proposed based on random waiting [15]. In this paper, cluster head candidates are selected based on their remaining energy and the locally random number generated. After waiting random amount of time, the cluster head candidates broadcast their announcement. Cluster heads are selected by base stations according to the demand of the network.

TB-LEACH revised the LEACH algorithm [16]. Nodes having shortest time interval become cluster heads. A counter is set to limit the number of CHs selected.

In other approach Cluster head and its back up are appointed based on their energy level to achieve fault tolerance [17]. If energy level of current cluster head falls below a certain limit or any cluster head fails to communicate then election process is started. Based on energy levels, election process appoints a cluster head and a back-up node to handle cluster head failure. Back-up node automatically takes over the role of cluster head once it detects failure of current cluster head.

For WSN another solution using Fuzzy logic (CHEF) is proposed [18]. In every round, sensor nodes generate a random number and compare it with a predefined value. If the random number is smaller, the sensor node calculates the chance using fuzzy if-then rule become candidate. Candidate node broadcasts a message and waits for other nodes. Node having greater chance value will be elected as CH.

To improve load balancing in LEACH protocol Leader Election with Load balancing Energy (LELE) is proposed [19]. LELE protocol selects CH on basis of remaining energy and distance of a node with its neighbors. Node with maximum energy and suitable position is chosen as the CH.

In another research work, CH Election is optimized using resource discovery mechanism [20]. Election process is managed by the resource discover technique. In this paper the information about types of nodes and their abilities are collected. The node having most efficient resources is elected as CH.

Another approach is proposed for CH election for WSN [21]. In this scheme any node which cannot communicate with CH broadcasts a cluster head announcement message. In this message the node announced itself as CH. If the receiver did not receive any announcement before it will elect the sender as a CH.

Another alteration to LEACH protocol was proposed to reduce power consumption of the WSN [22]. This paper was focused on minimizing the energy utilization of wireless sensor networks. Authors modified the probability of the traditional LEACHs cluster-head selection algorithm. The probability of is calculated based on its distance from the BS. Member nodes select the CH based on the signal strength of the message received from the different cluster heads.

Another technique was suggested which selects the Cluster Head on the basis of Radio Frequency (RF) signal strength [23]. Authors select the CH based on link quality of the nodes. According to this paper, each node searches for CH in their clusters. The node evaluates the RSSI of the reply from each CH if found. Strength of the received signal is compared with the required threshold value. If the strength is more than required value, the node becomes member of that CH. In case of multiple cluster heads, the node will become the member of the CH having maximum RSSI strength.

In another technique, authors estimated the number of clusters required for efficient data aggregation in a general sensor network and suggested an algorithm for cluster head election [24]. According to the algorithm, the node having largest numbers of one-hop neighbors and smallest communication distance will be elected as CH.

To increase the life time of WSN, another technique was suggested by modifying the traditional LEACH election [25]. In this technique, a set of nodes are selected randomly by the existing cluster head. Energy utilization of network with each node is calculated. The node having minimum energy consumption is elected as next cluster head.

The research optimization in LEACH protocol has been done to choose CH which can perform path optimization within a cluster and selects the number of rounds to allow another node to become a CH [26]. This process does not make any dissimilarity to cluster head rotation. This algorithm claimed to minimize energy utilization considerably to handle all node data**.** The new CH is elected on the basis of energy consumption of the node during network lifetime.

For even distribution of sensor nodes and to avoid re-clustering during each round ACE-C [27] select CH for each round based on node ID's. Initially all sensor nodes are assigned ID's from 0 to N-l (N is the number of nodes in the network). Depending on the number of cluster heads (C) required for each round the necessary number of nodes (with ID's from 0 to C-l) are selected as cluster heads for first round. For next round the nodes with ID's from C to 2C-1 are selected as cluster heads. To distribute the cluster heads evenly over the network, ACE-L [28] uses location information, provided in the form of reference points, to decide the cluster head during each round.

Based on number of cluster heads required equal number of reference points is fixed, a priori. The nearest among these points is used as a main reference point (MRP) by the sensor nodes. Nodes with same MRP values contend for the role and the one with minimum delay elects itself as a cluster head for current round. The nodes receiving the selection beacon from this cluster head leave the competition and join it as cluster members.

However both ACE-C and ACE-L needs clusters to be formed after each role rotation of cluster head. Particularly in LMSSC [29], the network is first partitioned into clusters by the base station and appropriate number of cluster heads is decided by evaluating a node metric which is defined, for any sensor node, as a ratio of its residual energy to the aggregate of sum of squared distances from a concerned sensor node to every other sensor node in the cluster and its squared distance to the base station.

In a communication range, sensor nodes first satisfying the fixed node degree criterion select themselves as cluster heads in MECH [30]. To decide on the cluster head role, during each round, all sensor nodes broadcast hello message to their neighbors and the nodes first receiving as many as pre-defined number of these broadcasts declare themselves as cluster heads and broadcast a cluster setup. Existence of exactly one cluster head is ensured in a communication range by not allowing the sensor nodes receiving the setup broadcast to broadcast again. The sensor nodes receiving the setup broadcast then send the joining requests and the cluster head after receiving these requests confirms the joining, prepares and distributes the time schedule for its cluster members.

Re-clustering, during each round, is avoided in an energy aware periodical data gathering protocol [31] by assigning the responsibility of selection of clusterheads, for subsequent rounds, to the initial clusterheads. To decide the initial clusterheads, all sensor nodes in the network compete for clusterhead role by broadcasting their ID's, in a predefined finite time, over a prescribed range. The nodes receiving the lower ID broadcast from any other node give up the competition without receiving the broadcasts of other remaining sensor nodes. Thus the nodes with lowest ID's in their prescribed transmission range select themselves as clusterheads and then broadcast their selection over the network area. The sensor nodes, based on received signal strength of these broadcasts, select the clusterhead one nearer to them to join, as cluster members and inform their selections accordingly. The primary clusterheads create schedule for election of other nodes as clusterhead during the network lifetime for their clusters. When remaining energy of the current clusterhead drops below certain threshold it broadcasts a role release message with its serial number and primary clusterhead ID. Listening this message, the next scheduled node declares itself as clusterhead and broadcasts an advertise message to all other nodes. In this stage, all the clusterheads perform the cluster formation process.

The clusterhead reconfiguration proposed in [32], also to avoid re-clustering, uses a strategy similar to [33] but instead of initial clusterhead preparing the schedule, current clusterhead decides on the sensor node to transfer its responsibility in subsequent round, considering the number of clusters and number of clusterheads within the transmission range of the non clusterhead sensor nodes in their clusters. However, selection of the initial clusterheads is not specified exclusively and they are assumed to be selected randomly or in a predetermined fashion. Considering that the non clusterhead nodes having same number of clusterheads in their range are placed into a small sub-region of the cluster, current clusterhead divides the cluster into several sub-regions and then select the nodes from different sub-region to work as clusterheads during different rounds. It is claimed that such a strategy distributes the clusterheads in fair fashion and balances the number of nodes in each cluster.

All sensor nodes communicate their position information and energy level to the base station in LEACH-C [34] and provide the necessary information to calculate the average node energy. Sensor nodes with remaining energy below this value are restricted from becoming clusterhead during current round. Base station finds the predefined number of clusterheads and divides the network into clusters, so as to minimize the energy required for non clusterhead members to transmit their data to the clusterhead. However formation of clusters with equal number of nodes in each of them is not guaranteed with this scheme.

To have approximately equal number of nodes in each cluster, BCDCP [35] selects sensor nodes having energy level above the average energy as probable clusterheads and the required number of sensor nodes, from these probable, having highest energy status, is assigned the responsibility during current round. Two clusterheads having maximum separation distance between them are used to divide the network into two clusters and the sensor nodes are divided so as to balance the clusters. This process of cluster division is repeated till the network is not divided in desired number of balanced clusters. After depletion of clusterhead energy below some predefined threshold the cluster setup phase is reinitiated, again.

Clusterhead selection strategy in power efficient routing protocol proposed in [36] also aims at even distribution of clusterheads, which it does by utilizing base station assisted k-means clustering to partition the network into clusters with iterative evaluation of the constraint function.

Clusterhead selection is carried out by the base station using position information received from all the sensor nodes for initial round and for successive rounds based on their residual energies as in LEACH-C [7].

The scheme using heterogeneous nodes is proposed in [38], which introduces a concept of strong head by proposing deployment of some nodes with higher energy, for increasing the network lifetime. These high energy nodes act as initial clusterheads and perform data gathering task. When energy in these nodes drops, below a predefined threshold, LEACH algorithm [8] is followed.

Initial clusterhead selection in an energy aware adaptive clustering protocol [39] is same as LEACH and for subsequent rounds current clusterheads decide eligibility of the sensor nodes in their clusters, based on remnant energy and empirical valued exponent of the received signal strength of selection messages received during set up phase. Current cluserhead chooses a node with maximum eligibility as clusterhead for next round and broadcasts its identification number (ID) along with TDMA schedule for current round and thus avoids reclustering.

In HEED [40], sensor nodes use residual energy as a criterion to decide on their role as a clusterhead and make up their mind setting the probability to a value expressed in terms of residual energy, maximum energy and the optimum percentage of clusterheads required for a particular data gathering round which is not allowed to fall below a minimum pre-defined threshold. If this value satisfies the eligibility criterion, the node declares itself as a tentative clusterhead. The probability is iteratively adjusted and when it attains unity value the node declare itself as a clusterhead. The process is repeated after specific time (every round). CMRP proposed in [41] also utilize the same clusterhead selection policy as HEED but instead of clusterhead transmitting directly to the base station a multihop minimum energy adaptive strategy is used by the clusterhead while forwarding the data to the base station. To improve upon HEED, heterogeneity of nodes is considered in DEEC [42] in terms of their energy in which node estimates average energy of the network at a particular round and uses it as reference energy. Then, based on this reference energy and its own residual energy, it modifies the optimum number of clusterhead value. With these adaptive values the sensor nodes decide probabilistically on their role during every round and use it as reference energy. Then, based on this reference energy and its own residual energy, it modifies the optimum number of clusterhead value. With these adaptive values the sensor nodes decide probabilistically on their role during every round.

In EECS [43], all nodes in the network become candidate nodes with certain probability and compete among each other and broadcast a compete message within a radio range. The nodes competing on finding another broadcast having higher energy gives up the competition. Thus in each radio range the candidate node with highest residual energy is selected as a clusterhead.

A combined metric deterministic and adaptive clusterhead selection is carried out in LNCA [44] in which, all nodes in the network sense the environment data and broadcast it to their immediate neighbors and in turn receive the data from same set of nodes. If the received data from any of its neighbors is the same, as its own sensed data, it increases its node degree by one and then stores the ID's of the nodes with same sensed data. Every node then broadcasts its node degree and the residual energy to the immediate neighbors and in tum receives the same information, from its neighbors. The nodes decide to become clusterhead using node degree as the primary and residual energy as secondary criteria. Then also, if there is a tie the node with lowest ID declares itself as a clusterhead. The selected clusterhead continues in its role for few data reporting intervals, depending on environmental stability.

Weights are assigned to residual energy, node degree, sum of the non clusterhead member distances and the distance to the base station in DWBCA [45]. During clustering each node computes its distance from the base station based on the received signal strength of the control information sent by the base station. Each node initially is in READY state and may be in READY, CLUSTERHEAD or CLUSTER MEMBER state at any given time. The nodes in READY state maintain the neighbor table by broadcasting neighbor discovery and exchanging the information containing their node ID, residual energy and distance to the base station. They also can estimate their mutual distances from the signal strength of these information exchanges. Then the nodes compute their weight and exchange it with their neighbors. The nodes with lowest weights among their neighbors are selected as clusterheads.

Rest of the nodes joins the closest clusterheads. During clusterhead rotation the neighbor information is already available with the nodes and by just exchanging the weight information next clusterhead is decided.

In EECR [46], the clusterheads are elected for initial round by the base station by partitioning the network into clusters and assigning the role of clusterhead to sensor nodes that are located at cluster centers. The selection of subsequent clusterheads is made by the current clusterheads based on the weight values of sensor nodes, which is defined as a linear combination of the remaining energy at the node, number of neighbor nodes and the time required for becoming a clusterhead in former rounds. Current clusterhead compares the maximum weight value with its own value and if finds higher continues in the present role otherwise becomes a cluster member and

Table 1: Comparison of CH election in WSN

| | Parameters | | | |
|---|---|---|---|---|
| Author (s) | Location | Throughput | Energy | Single CH Elected |
| Heinzelman *et al*., 2000 | X | X | ✓ | X |
| Handy *et al*., 2002 | X | X | ✓ | X |
| Gupta *et al*, 2005 | ✓ | X | ✓ | X |
| Hyung *et al*., 2006 | ✓ | X | ✓ | X |
| Haiyan *et al*. 2007 | X | X | ✓ | X |
| Kim *et al*, 2008 | ✓ | X | ✓ | X |
| Junping *et al*. 2008 | X | X | X | ✓ |
| Mehdi *et al*., 2009 | ✓ | X | ✓ | X |
| Raza *et al*., 2009 | Undefined | | | |
| Buttyan *et al*, 2009 | X | X | X | X |
| Y. Yaoyao *et al* 2009 | ✓ | X | ✓ | X |
| O. Zytoune *et al*., 2009 | X | X | ✓ | X |

notifies the node with maximum value to be the clusterhead for next round. In the case of more than one node satisfying eligibility criterion, nearest one is assigned the job.

All above mentioned Cluster head selection strategies in WSN are compared below in Table 1 with respect to the parameters of location, energy and chances of multiple CH election.

**CH Election in MANET:** All the above mentioned research work is in the scenario of wireless sensor networks. WSN and MANET have some common features like limited battery, mobility issues etc. However, there applications of the WSN are not applicable in MANET because of the following reasons.

Sensor nodes in WSN are designed to sense data and send to the central authority; however the nodes in ad hoc network may have complete processing capabilities e.g. laptops, cell phones etc. WSN has a central authority called base station, whereas MANET is a completely independent network without any infrastructure.

These differences raise the need of some other solutions for election processes which are designed for ad hoc networks.

Weighted Cluster Algorithm (WCA) is proposed for MANET [47]. WCA elects the CH based on the mobility, ability to handle nodes, communication range etc. The algorithm calculates the average weight of each node based on the provided factors. The node with the minimum weight is selected as a cluster head.

In K-hop connectivity ID clustering algorithm (KCONID) [48], the node having maximum connectivity is elected as CH. If two nodes have same connectivity value then its selects node having lower ID as CH.

Another approach is used for dynamic CH election based on energy level of the node [49]. In this approach nodes share their IDs and energy value using broadcast messages. After random time t, the node with maximum energy level will be elected as Cluster Head. If two nodes have same energy level, the node having maximum number of neighbours will be elected as Cluster Head.

An identifier based clustering algorithm is proposed [50]. In this scheme a unique ID is assigned to each node. The node having minimum ID is elected as cluster head. Degree of a node is calculated by every node on the basis of distance parameter. If the Euclidean distance [51] within the transmission range, the node will be elected as CH.

Two variants of the cluster head selection, distance-constrained and size-constrained, are proposed for MANET [2]. Two different algorithms are proposed for cluster head election. First algorithm is proposed for distance. According to this algorithm CH is selected if every member node is within a limited distance from the nearest CH. Second algorithm is based on the size of the cluster, where each cluster is only allowed to have a limited number of members. In this case CH is selected such that the size of each cluster is not larger than a predefined value.

Another solution for CH election is proposed for MANET [52]. In this paper authors proposed an Adaptive Invoked Weighted Clustering Algorithm, which maintains stable clusters. In Weighted Clustering Algorithm (WCA) a node is selected to be the cluster-head with minimum weighted sum of four indices -node degree (number of direct link to its neighbors), sum of distances to all its neighboring nodes, mobility and remaining battery power respectively [47]. WCA lacks in knowing the weights of all the nodes before starting the clustering process and in

Table 2: Comparison of CH election in MANET

| Author (s) | Parameters | | | |
|---|---|---|---|---|
| | Location | Throughput | Energy | Single CH Elected |
| Chatterjee M *et al* 2000 | X | X | X | X |
| G. Chen *et al* 2002 | X | ✓ | ✓ | X |
| R. Aganval *et al* 2009 | X | X | X | ✓ |
| li xu *et al*. 2009 | X | ✓ | X | X |
| Chatterjee. 2009 | ✓ | ✓ | ✓ | X |
| R. Aganval *et al* 2009 | ✓ | X | X | X |
| Dang Nguyen *et al*. March 2011 | ✓ | X | ✓ | X |
| S.Rohiui *et al* Feb. 2011 | ✓ | X | ✓ | X |

draining CHs rapidly. To solve this problem S. Rouhini propose a probability based adaptive invoked weighted clustering algorithm (PAIWCA).This can enhance the stability of the network by taking battery power of the node into consideration for selecting cluster-heads and for forming clusters. The weight of a node is calculated before the clustering process thus by minimizing the overhead of re-clustering in electing a cluster-head.

Reputation-based Trust Management Strategy for Clustered Ad Hoc Networks is proposed for clustered ad hoc networks [53]. In this paper a cluster head backup mechanism was maintained. The existing CH selects its backup who has maximum trust value. Cluster head updates all the information to its backup. If CH cannot communicate with other nodes, it transfers this role to the backup CH.

Another trust based approach is proposed for MANET [54]. In this work, any candidate for CH broadcasts the message with its mobility, battery power value to all its one hop neighbors. Receivers calculate the global weight of the sender by using the received information and adding trust value of the sender. If global weight is greater than a predefined value, the receiver will vote for the sender. After a certain time, the candidate node will count the votes. If number of votes is greater than half of the number of members, it advertises itself as leader.

Another approach is proposed for ad hoc networks [55]. The proposed approach uses a semi-meshed Public Key Infrastructure (PKI) model. In this scheme, the trust value of every node is calculated and the node having maximum trust value is elected as cluster head.

Another approach is proposed for WSN networks [56-58]. The author proposed different parameters based selection of Cluster Head. In this scheme, the energy level, distance from the sink and number of neighboring nodes in same grid is calculated and based on them the cluster head selected.

We have compared above mentioned techniques in Table 2. in this table we compared the techniques and highlights the parameters used in the above solutions. We also highlight the handling of case of tie in above mentioned algorithms.

## CONCLUSION

Cluster Head selection is one of the key research issues in cluster based MANET. Many CH election mechanisms have been proposed in the past. The main objectives of these previous solutions are energy efficiency and routing. In almost all the previous researches, more than one CH can be elected during one election process. In case of a tie, no alternate solution is given. Throughput of the node is an important aspect which is ignored in almost all the proposed mechanisms. Almost all the intra cluster traffic must pass through the CH; therefore it must be able to handle maximum packets. Hence a solution is needed which ensures the selection of a reliable cluster head, which can handle maximum traffic. Also the solution must select only one cluster head during one election process.

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