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Evaluation of Routing Algorithms Based on Clustering in Wireless Networks

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Abstract—Nowadays, computer science has made progress to the point that many other sciences' progress is related to computer science. Computer networks have made progress to the point that they have turned the world into a small scientific village. To make a communication between these networks we need to have a spinal column, this underlying network has been made of many routers that they task is to transmit information. Some algorithms should be implemented on these routers so they could find the best route to transmit the information to this village. This paper is about routing in wireless networks, evaluation of various routing algorithms, analysis, and the way of implementing these algorithms to be applied.

Index Terms— Wireless, Evaluation, Clustering, Algorithms, Routing, Networks

1 INTRODUCTION

THE network nodes classification to some virtual groups to reduce the routings overheads and other applications in the network are the some of the conventional methods in network protocols. This method is commonly called clustering. In clustering algorithms, the MANET network is divided into a number of virtual groups that each of them is called a cluster. Mobile nodes in each cluster are geographically adjacent to each other. In each cluster, one node is chosen as the cluster head (CH). The rest of nodes are the member of other clusters. The maximum distance from each node to the cluster head is called cluster radius. Cluster radius is one of the clustering algorithm design parameters and it is expressed based on the number of intermediate nodes. Most of the provided algorithms are one step algorithms; it means that they are the cluster members in the distance of one node to the cluster head. Some algorithms are multi-stepped. Because in the distributed clustering algorithms, complexity and communication overheads to create the clusters will increase with the cluster radius increase. In the proposed algorithm so far, the cluster radius has not exceeded the two nodes. Figure 1 shows a sample of clustering in the Ad Hoc network. In this figure, clustering is considered with the maximum two-step radius. In this example, the 5, 7 and 11 nodes are chosen as the leader, and the rest of nodes each one is the member of mentioned leaders.

So far, several clustering algorithms have been proposed for Ad Hoc Networks. The provided algorithms choose the CHs with various methods.

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2 THE ADVANTAGES OF CLUSTERING

According to what was expressed in the previous parts about the limited capacity of Ad Hoc networks, in the applications such as routing and distribution of information, using the hierarchical structure to optimize the network capacity seems necessary. In fact, clustering is a way of achieving such a hieraarchical structure. In fact, with the implementation of clustering algorithm, nodes are divided into a number of virtual groups. Heads of each of these groups will take the main burden of routing within the groups. The gates nodes are also responsible for data transportation between the two adjacent clusters. Thus, the group heads and gates nodes of a network will create the communication virtual backbone. Figure 2 show's the relationship between routing applications and distribution of data with clustering in the layered structure of each node.

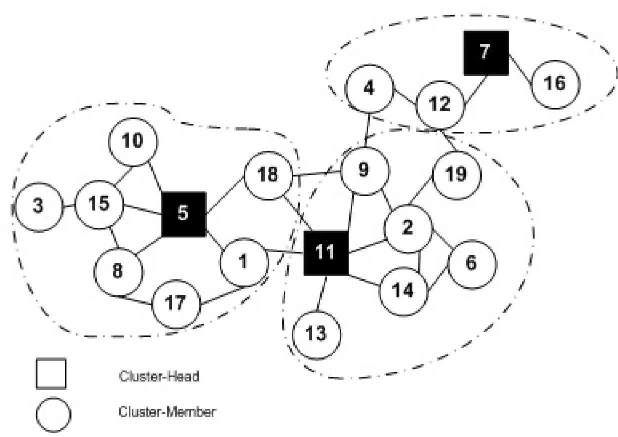

Figure 1 example of clustering in the Ad Hoc network.

As it is shown in the figure, clustering is implemented in the 3 layers. Routing protocols and data distribution are also placed in this layer and use the clustering services. By using clustering in the routing and distribution of data, only the head and

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gates nodes are responsible for routing or distribution of controlled data to other nodes. This brings the following benefits:

- The number of control packages in the network will be reduced and network capacity utilization would be saved. This will reduces power consumption in the mobile nodes. In addition, all the mobile nodes are not obligated to save the routing tables. Thus, the use of network resources will be reduced.
- Mobility of nodes will have less effect on the router performance. Each node routing data is only saved in the head related to the cluster of that same node. The movement of a node from one cluster to another cluster only changes the data of the two heads of the network [1].

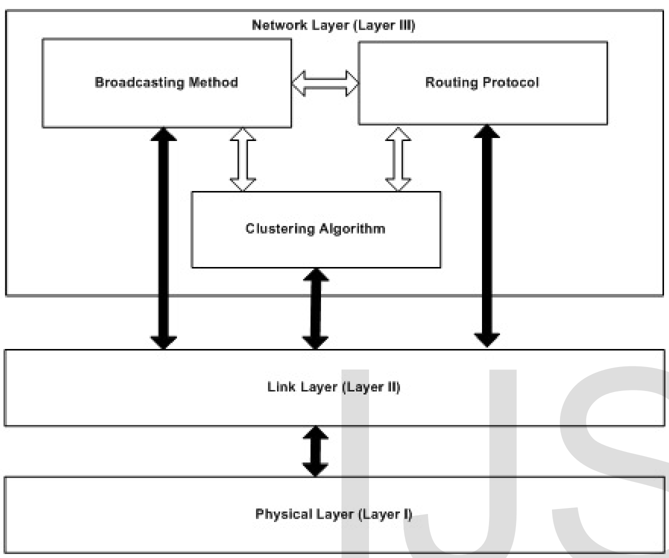

Figure 2 clustering in the layered structure.

3 HIERARCHICAL ROUTING ALGORITHMS BASED ON CLUSTERING

In this section we will review the clustering methods based routing. Various routing methods based on clustering are presented, in this section are some of them will be discussed. CGSR is one of the algorithms based on Table-Driven clustering. In CGSR, the sending package is sent from each node to its head and from the head to the gate. Since then, sending from the gate to the head, and from the head to the gate happens until, the data package reaches the destination node of the cluster. That is where eventually the package reaches the destination system. Figure 10-1 is an example of CGSR.

As it is seen in the figure, in order to send the information from the node 14 to node 2, the heads 5, 7 and 11 and gates 1 and 9 are placed in the data transmission route. CGSR is in fact based on DSDV, but by using clustering, it tries to improve routing efficiency. In this method, each node should keep a Cluster Member Table that includes the cluster of each node in the network. These tables using DSDV method are sent periodically by each node. The other algorithm that is presented is CBRP. This method in fact is the improved DSR in order to use clustering algorithm. In this method each head should know their adjacent clusters. For this reason, each node stores a table of adjacent heads address and places these addresses in the hello sending packages. Thus, the head by receiving the Hello messages from their adjacent groups will be notified of the adjacent clusters.

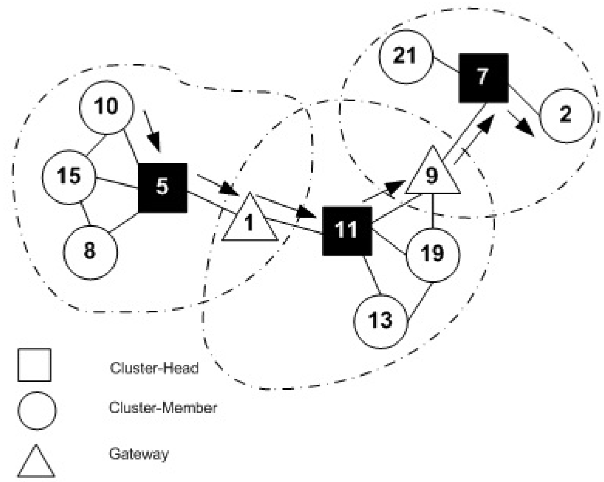

Figure 3 an example of CGSR routing algorithm.

At the time of request by the source node, the head should distribute the route request packages to the adjacent heads. Like DSR, in the request packages during the passage through the nodes, the address must be included in the package, unlike DSR; only the address of heads that the request package has passed them is recorded.

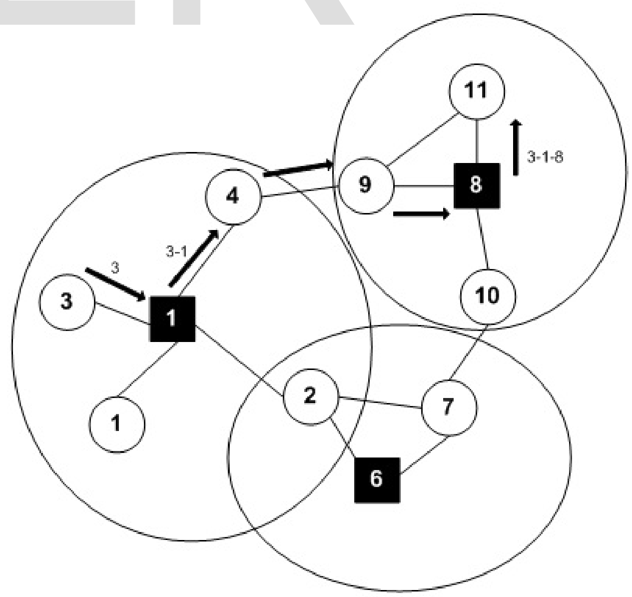

Figure 4 is an example of the phase of finding the routes in CBRP process.

Figure 4 routing in the CBPR algorithm. In [2], another routing algorithm is considered based on clustering with the radius if

ISSN 2229-5518

2 nodes. In this method, two types of routing algorithms are used. Routing within use DSDV method and routing between the clusters uses the On-Demand method like AODV. As a result, in the routing between two nodes, if both are within a cluster, routing happens with DSDV method. If two nodes are in the two separate clusters, the head of source should begin the process of finding the route and by finding the destination clusters it should implement the routing. It should be noted that using a combination of two routing methods will have a significant impact on the routing efficiency improvement. Among the other provided results of [2] we can refer to the optimal effect of created clusters stability on the routing efficiency improvement.

4 A REVIEW OF CLUSTERING ALGORITHMS

Presentation of clustering algorithms at first was done with two methods: lowest-ID and max_Degree. In the lowest-ID method each node ID is used to determine the head. Since clustering is implemented in the network layer, each node ID is the node IP address too, which is a 32 bit number. Lowest-ID algorithm is used by a 1-hop algorithm. As a result, the clustering radius is considered as one node. In this algorithm, each node that has the lowest ID among its neighbors will be the head. In other words, the head will see the nodes with greater ID within their one-step radius. Figure 5 shows an example of this algorithm. In this figure, the nodes 1, 2 and 4 are chosen as the heads.

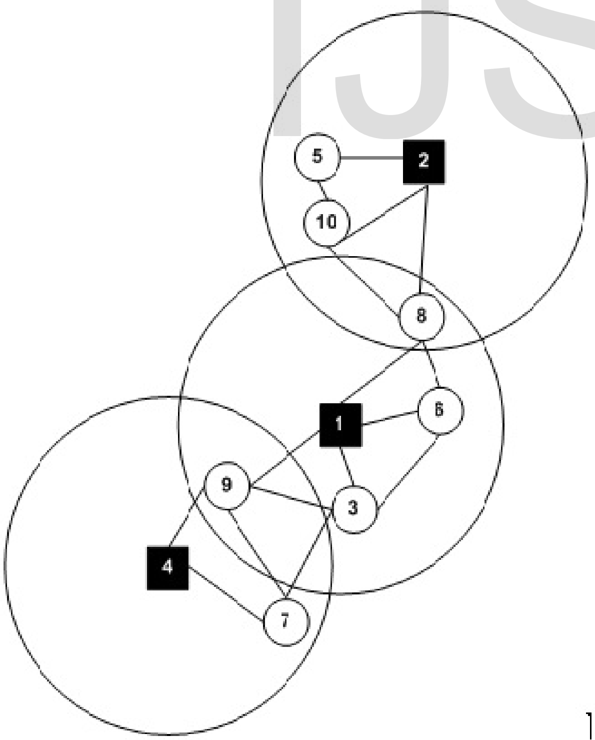

Figure 5 clustering with the Lowest-ID method.

In the max-Degree method, the number of neighboring nodes is the main decision making parameter. Thus, the node is chosen that has more number of neighbors. The number of neighboring nodes is the measure of Connectivity. In [1] both methods have been implemented and their efficiency parameters have been evaluated. In this paper, the number of created clusters is considered as a criterion of scalability, and the number of heads changes is considered as the major criteria of sustainability. By doing simulation on both models of lowest-ID and max-Degree and studying the results, it is shown that the lowest-ID algorithm has more sustainability than max-Degree algorithm. In other words, the number of heads changes in lowest-ID is less than the number of heads changes in max-Degree. Lowest-ID and max-Degree ideas are used in many of the presented clustering algorithm. Another clustering algorithm that first the time has been raised in the lowest-ID discussion is called LCA. In this algorithm, nodes communicate with each other by sending TDMA packages. In this package, to prevent collisions, a Slot is assigned to each mobile node. In [3] Lowest-ID method has been modified to increase stability. In this article, the algorithm called LCC increases stability in the lowest-ID. In this method, only in two situations, there is a possibility to change the role of a head to a common node.

- If the two heads are placed in their clustering radius and will be forced to compete for being the head.
- When a node is removed from its cluster and won't be placed in the other clustering area of any heads.

The CGSR algorithm that was mentioned is presented based on LCC algorithm. In [42] an improved method of LCC that is called MOBIC is presented. In this method, the nodes mobility is considered as a parameter in the algorithm. By calculating the relative velocity variance compared to neighboring nodes, an estimation of the node velocity will be obtained. The lower variance represents lower speed. In MOBIC the nodes with lower velocity are chosen as heads. The parameter that is used to estimate the relative velocity of the two neighboring nodes in MOBIC is the ratio of input power (RXP2) of a node in receiving two alternate data packages from one node. Using this parameter, we will obtain an estimation of direction of the relative movement of two nodes and also the relative velocity of two nodes. In the Friis model it is shown that the ratio of output power to the transmitted power has a reverse proportion with the sender and receiver square of the distance. In the real model, we cannot obtain the exact distance, but with the RXP2 proportion in two alternate transitions, we can obtain an approximation of the relative movement of the neighboring node. Thus, the relative mobility parameter in MOBIC is defined as follows:

$$M_Y^{rel}(X) = 10\log_{10}\frac{R_x P_{r^{new}_{X\longrightarrow Y}}}{R_x P_{r^{old}_{X\longrightarrow Y}}}$$

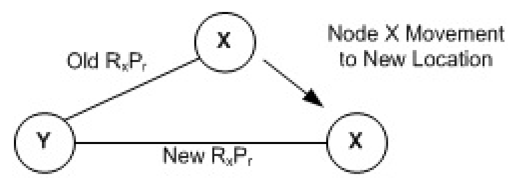

Figure 6 the defined mobility parameter in MOBIC.

According to figure 6, if M■(rel@Y)(X) is smaller than zero , It can be concluded that two nodes are moving away from each other. If this parameter is greater than zero it is concluded that the two nodes are approaching each other.

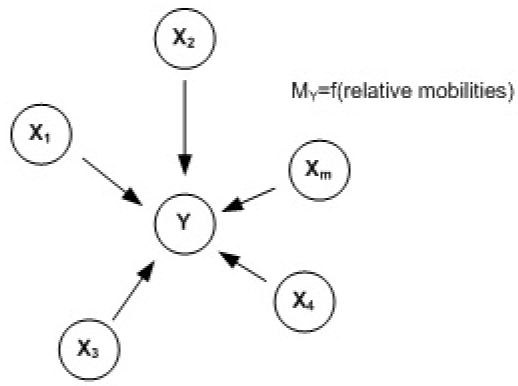

Figure 7 received power when receiving packages from neighboring groups.

As it is shown in figure 7, given the number of nodes Y neighbors, in the MOBIC method the MY parameter is considered by calculating the variance of the calculated values for all the neighbor nodes:

$$M_Y = \mathrm{var}_0\left(M_Y^{rel}(X_1), M_Y^{rel}(X_2), \ldots M_Y^{rel}(X_m)\right) = E\left[\left(M_Y^{rel}\right)^2\right]$$

In the MOBIC algorithm in each node by receiving the continues Hello messages from the neighbor nodes, this parameter will be calculated and placed in the Hello messages that are sent by the node. When determining the head, the node with less MY is chosen as the head. In the other category of clustering algorithms the Dominating Set (DS) idea is used [4]. According to the definition, in a G graph that includes the mobile nodes of the MANET network, a set of nodes with the name of S is considered as a DS that each node is from the G graph or a member of S or a neighbor of S members. This definition in fact should be named as 1-hop DS definition. This definition can also be generalized to d-hop DS. Based on this definition, in a G graph the S set is called a d-hop DS set, if each node of the network would be a member of S or at most would be at the d node distance from one of the S members. Figure 8 is an example of 2-hop DS in a MANET network.

As shown in the figure, the set of { 1,2,6,13} nodes will form a 2-hop DS, because all the network nodes are at most in the 2-node distance from one of the members of this set. In [4] there is a clustering algorithm based on d-hop DS that is called max-min. this algorithm is also based on nodes ID and is not based on max-Degree. In max_min, for clustering (with d radius) two operational phases are considered. Before starting the first phase, each node will initialize a variable with the name of WINNER with its ID number. At the first phase that is called floodMax, each node will send its WINNER to its neighboring nodes in d times. Each node by receiving the control packages from the neighboring nodes initializes its own WINNER value with the maximum received values and the pervious value of WINNER. In other words it is as follows:

$$WINNER_i = Max\left\{ WINNER_i, WINNER_i^1, WINNER_i^2, \ldots WINNER_i^n \right\}$$

At this phase is similar to the first phase, the WINNER transition happens at d times. Upon completion of the second phase, in each node the WINNER achieved values of in the first and second phases are evaluated.

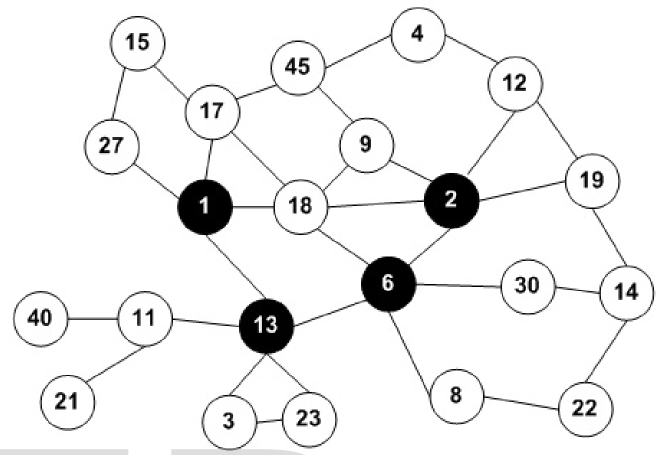

Figure 8 an example of 2-hop Dominating Set.

The smallest ID that is chosen in both phases as the WINNER, it will be considered as the head of that node. If the node ID at the second phase is chosen even one time as the WINNER, that node is introduced as the head. Figure 3-5 shows an example of the implementation of max-min algorithm for the 3-step clustering. The 1 table shows the stages of the algorithm implementation at the two phases.

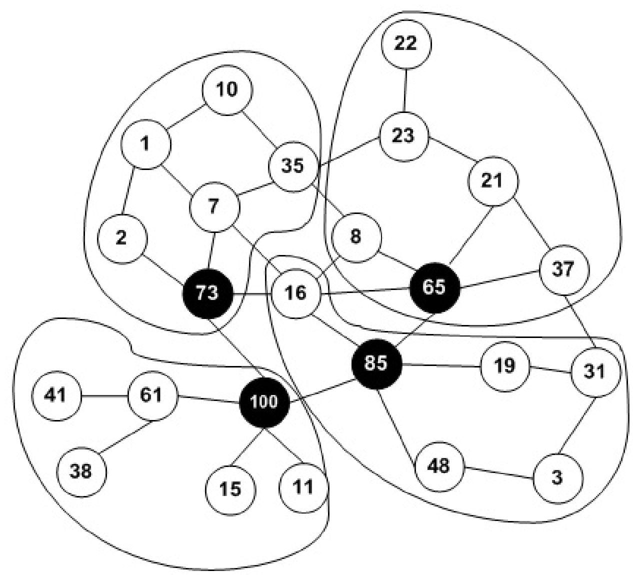

Figure 9 an example of clusters formation in the max-min method.

In [4] this algorithm has been implemented and its efficiency parameters with simulation in different environments have been evaluated. The simulation results show that the stability of this algorithm than the LCA and max-degree algorithms have impressively increased. However, this algorithm is implemented continuously like LCA algorithm. In other words, the algorithm implements at specific times and the whole clustering structure will form the beginning. For example in [4], this algorithm implements at each 2 seconds. At each stage of algorithm implementation, a 2d time is required so the algorithm will be implemented perfectly.

Table 1 the steps of max-min method implementation

Node	10	1	2	7	35	8	23	22	21	65	37	31	19	85	16	100	73	28	41	61
Max 1	35	10	73	73	35	65	35	23	65	85	65	37	85	100	85	100	100	73	61	100
Max 2	35	73	100	73	73	85	65	35	85	100	85	85	100	100	100	100	100	100	100	100
Max 3	73	100	100	100	100	100	85	65	100	100	100	100	100	100	100	100	100	100	100	100
Min 1	73	73	100	100	73	100	65	65	85	100	100	100	100	100	100	100	100	100	100	100
Min 2	73	73	73	73	65	73	65	65	65	85	85	100	100	100	100	100	100	100	100	100
Min 3	65	73	73	65	65	65	65	65	65	65	65	85	100	85	73	100	73	100	100	100
Result	73	73	73	73	73	65	65	65	65	85	65	85	100	85	100	10	73	100	100	100

5 The Clustering Algorithm Based on Sustainability

The purpose of the proposed algorithm is the implementation of a method for clustering of mobile nodes in a multi-step way. In this algorithm, stability is considered as the most important optimization parameter. Thus, this algorithm is named clustering algorithm based on sustainability. Figure 3-6 shows the implemented algorithms for clustering.

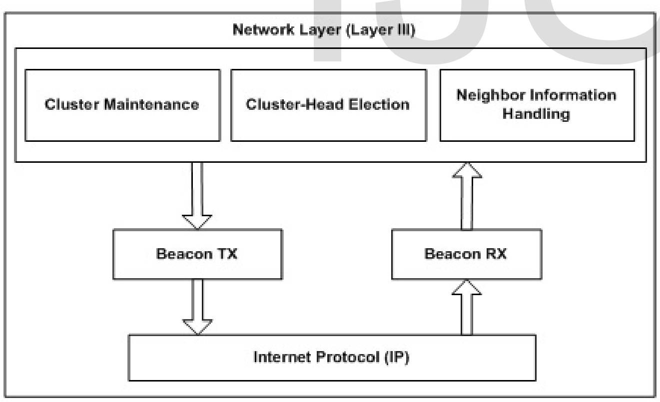

Figure 10 the implemented structure for clustering.

In this algorithm, in addition to sustainability, scalability has been also considered. Therefore, two points has been considered in the design of this algorithm. First, to improve the scalability, according to what was mentioned in the previous sections, the method based on max-Degree is used. Second, to increase sustainability, as we shall see, with the definition of parameters for sustainability, it has improved the clustering sustainability. As we will see in the efficiency evaluation part, this method in addition to its scalability has a higher sustainability than the algorithms based on lowest-ID. In this algorithm, each node will distribute in the Beacon continues method. The distributed Beacons are received by the neighboring nodes and will be used to update clustering data and data of neighboring nodes.

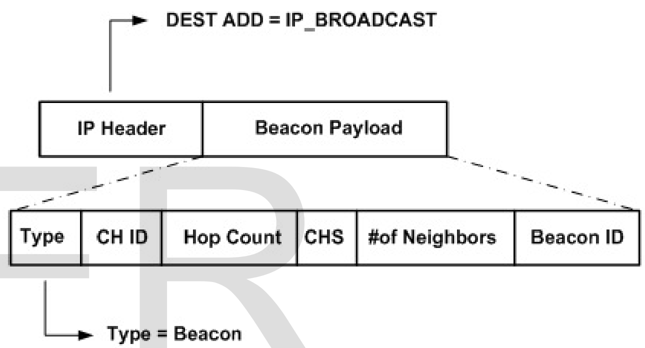

Figure 11 shows the arrangement of Beacon packages.

As it is seen in the above figure the data contained in the Beacon packages are as follows:

- According to different packet types, as we shall see in the following sections, with the inclusion of the an area in the transmitted packages, we can determine its type
- CH: This section contains the Cluster-Head of the Beacon sender node address
- Distance to CH: This shows the Beacon sender node distance from CH according to the number of hop counts. Zero in this field indicates that the Beacon sender is the same as CH
- CHS: This integer indicates the number of Beacons that from the beginning CH has sent them as the CH. In other words, this parameter in Beacon explains the sustainability record of CH
- Number of neighbors: Each node in the transmitted Beacons records the number of its CH neighbor nodes
- ID: This is an integer that by sending each Beacon, it increases one unit. This parameter is used to test the Beacon validity in the receiver

So, after receiving Beacon from the neighboring nodes, each node will obtain an estimation of the heads that are close to it and its distance from them and also their relative sustainability.

ISSN 2229-5518

Neighboring nodes

Sending periodic messages to neighboring nodes that are directly in the scope of nodes vision is common in all the clustering methods in order to make the nodes aware of their neighboring nodes [5].

In the algorithm based on sustainability also Beacon is used to detect the neighboring nodes. Each node by receiving the Beacon from a mobile node puts the Beacon sender node address on the list of its neighbors. If the particular amount of Beacon is not received from the neighboring nodes, it means that the mentioned node is no longer in the neighborhood. This may be is due to the node mobility or the neighboring nodes mobility. The data that each node stores on its neighbor nodes are given below:

- Neighbor node address
- Neighbor node CH address
- CHs related to neighboring node CH
- ID of the last received Beacon from the neighboring node

Among this data, the neighboring node address is extracted from the IP head of the received Beacon, the rest of the data can be extracted from the Beacon data.

Cluster Formation

Cluster formation in the algorithm is composed of two phases:

- Contention Phase

In this phase, all the nodes, by placing their address in their CH introduce themselves as the heads. In the competition between the two nodes, the node that has more CHS and also more neighbors will be successful. Each of the two nodes that their distance is less than d, will compete with each other to obtain the role of head. This phase continues by each node at a specified time.

- Stability Phase

This phase is similar to the previous phase with the exception that the condition of the competition of the two CH in addition to competitive conditions in the previous phase is that Both CH should be sustainable.

Each CH will be assumed sustainable if its CHs are more than a Stability Threshold. In other words, in this phase, the only changes that will occur in the cluster structure is because of the mobility of the nodes, and this is the nodes mobility that put two heads at their neighborhood and as a result make them to compete with each other. When a node by receiving the Beacon from its neighbor decides to join the mentioned cluster in the Beacon, it will update its data from the head based on the data on the Beacon. In this case, the neighboring node that has sent the Beacon is called Cluster-Agent. The data on this neighbor is registered in the member node as the Cluster-Agent. In other words, the new member by its Cluster-Agent is connected to Cluster-Head. The role of Cluster-Agent in the algorithm is somewhat similar to the Next-Hop node role in the DV routing algorithm. For example, in figure 8-3 we see a schematic view of a two-step clustering. In this figure, the node 7 plays the head role. The node 4 is introduced as a member of the related head, and node 9 is considered as its head, because only by receiving the Beacons of node 9 the node 4 can receive the clustering data of node 7. As it can been seen in the figure, the node 5 that before that was introduced as the head, now given the number of neighbors has changed its role and turns to a member of the cluster related to node 7.

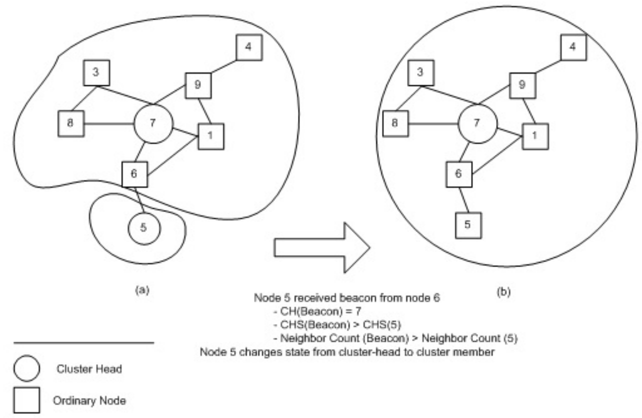

Figure 12 an example of two-step clustering in an Ad Hoc network.

The implemented algorithm in the heads at the time of receiving Beacon from each of the neighboring nodes is shown in figure 13 As it is shown in the figure, in this algorithm the condition of the two heads competition is their sustainability and distance less than d. if one head fails in the competition and decides to be a member of the winning head, it will search the head address among its neighbors so that if was among the neighbors, it can update the data of its distance based on the data in its neighbors.

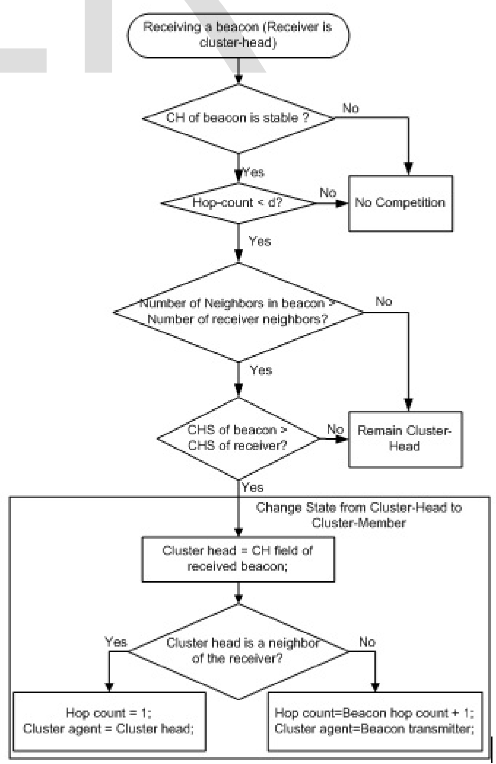

Figure 13 the implemented algorithm in a head by receiving one Beacon.

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6 Cluster Reconfiguration

Because of the mobility of nodes, the change in structure and cluster reconfiguration is an inevitable issue. The amount of these changes is dependent on Node mobility speed. From the perspective of each network node that is a member of a cluster, the cluster changes by looking at the data from Cluster-Agent are understandable. If Cluster-Agent is eliminated from the list of neighbor nodes, this represents the node movement or the Cluster-Agent movement in a way that they won't leave their scope of vision. If the head leaves the cluster (with a distance of more than one step) this can detected by changing the head of the received Beacons from the Cluster-Agent.

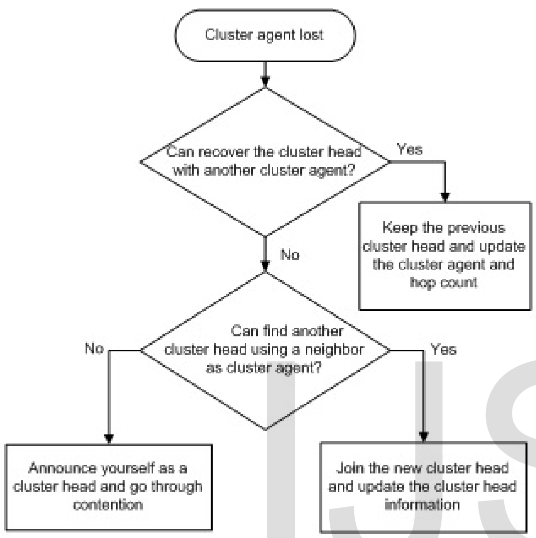


Figure 14 shows the implemented algorithm in a normal node that cannot see its Cluster-Agent in its neighboring area.

As it can be seen in the picture, the node tries to find another Cluster-Agent its neighboring area, so it could still remain in its previous cluster. If it is possible, only Cluster-Agent and some of the clustering data such as distance to the head will change. Otherwise, the node tries to join another cluster in its neighboring area. Figure 3-10 the implemented algorithm in a normal node that has lost its Cluster-Agent. If it was not possible, the node will announce itself the head. It is obvious that it is tries to keep the previous cluster; otherwise, the changing role of node from a normal member to a head will be prohibited. Figure 15 shows two examples of the algorithm performance in the disappearance of Cluster-Agent. In part (a) the nodes 5 and 7 are introduced as the heads. The node 10 is one of the members of the head 7, and it has considered the node 1 as its Cluster-Agent. In part (b) the node 1 has left the 7 head area. The node 10 by being notified of the disappearance of its Cluster-Agent refers to other neighbors chooses the node 4 as its new Cluster-Agent and remains a member of the head 7. In figure (c) you can see that the node 10 like the previous situation has lost its Cluster-Agent but it cannot find any alternatives to replace it to stay in the head 7. The only available option for node 10 in this situation is to choose the node 2 as its Cluster-Agent. As a result, since then the node 10 is a member of the head 5.

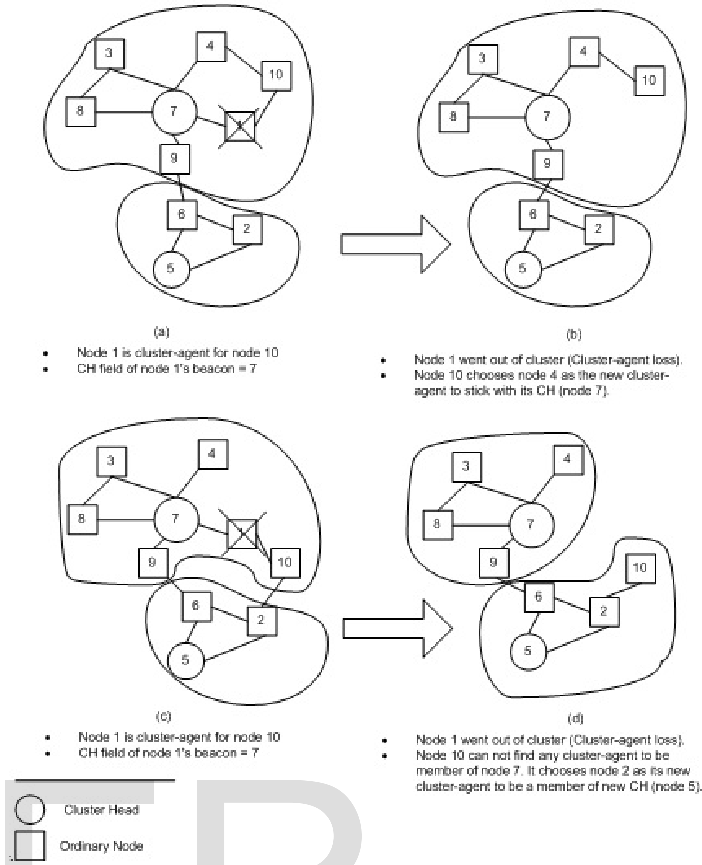
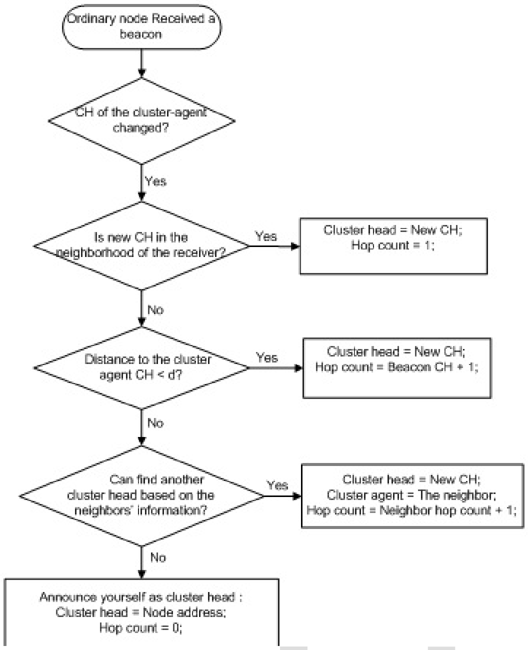


Figure 15 shows an example of the algorithm performance in the disappearance of Cluster-Agent.

If the head leaves the cluster (more than one step distance) the CH part will change the transmitted Beacons of the Cluster-Agent, because the neighboring nodes of the head are disappeared, so according to the mentioned above method it will try to find the new head and this will continue to Cluster-Agent of all members of the former head. So the cluster members by observing the change in the CH part of the received Beacon from their Cluster-Agent will be aware of the head disappearance.

Figure 12 the implemented algorithm in a node that has seen a change in the CH of its Cluster-Agent. As it can be seen in the figure, the mobile node tries to join the new CH of its Cluster-Agent. If it was not possible, it will search in its neighbor data to find another head so the Cluster-Agent of this node will be changed. Even if this does not happen, the related node will announce itself as the head. Figure 12-3 shows an example of the clustering algorithm performance in this situation. As it can be seen in part (a) the node 10 is the member of the head 7 and node 1 is the head. The clustering radius is considered 2-step. By the movement of node 7 and the selection of node 8 as the new head in part (b), the CH part in the transmitted Beacons of node 1 will contain the node 8 address. The node 10 by receiving the Beacons of the node 8 will be aware of the head change and since then it will a member of the head 8. In parts (c) and (d) the same thing is showed, with one difference that here the distance of the node 10 to the new head (node 8) is more than the authorized radius of the cluster, and the node 10 cannot be a member of node 8.

Figure 16 shows the implemented algorithm in this situation.



So by selecting the node 2 as the Cluster-Agent it will choose the node 5 as its head.

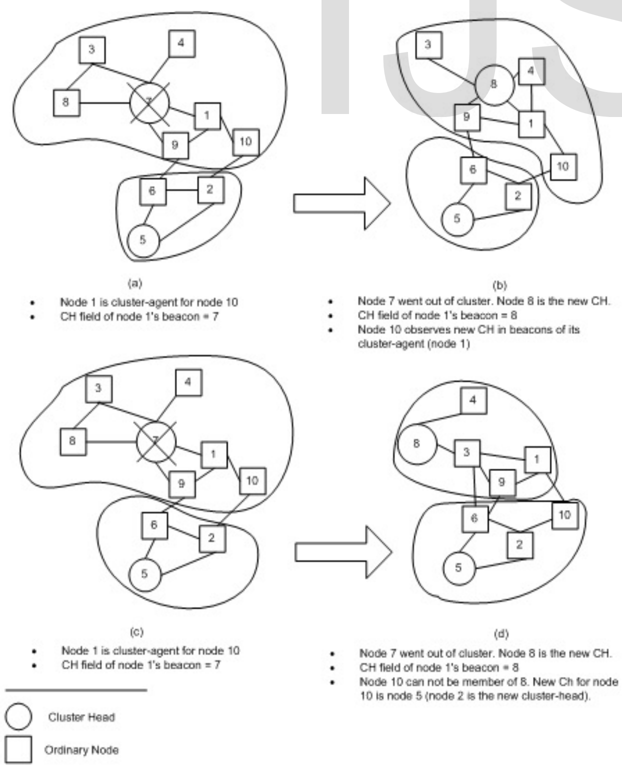


Figure 17 an example of algorithm performance if the CH of the Cluster-Agent changes.

7 PERFORMANCE EVALUATION

In order to evaluate the performance, the algorithm based on sustainability is simulated by the network simulation software NS-2 [6]. For this purpose, clustering algorithms in the form of an Agent with other codes in this software is compiled and made. As a result the resulted NS-2 contains the algorithm that is based on sustainability. To obtain the algorithm performance parameter the TCL environment is used.

The algorithm efficiency assessment has been done in the following ways:

Studying the effect of the number of mobile nodes on the performance of network parameters.

For this purpose, a square with dimensions of 2500m × 2500m, is considered. In each simulation respectively 100, 200, 300 and 400 mobile nodes have been arranged randomly in this area. The mentioned nodes mobility model Random Waypoint is considered with the following table parameters.

Table 2 Mobility model parameters used in the simulation

Random Waypoint Parameters	
Max Speed	125 m/s
Pause Time	4 Sec
Total Simulation Time	100 Sec
Number of Nodes	100, 200, 300, 400
L×L	2500×2500
TX-Range	250m

As it can be seen in the following table, a high mobility speed (125 m / s) is considered for the nodes so the algorithm parameters can be measured in the high mobility speed. Clustering is also implemented in the two-step method. The parameters are assessed as follows:

- The average number of produced clusters

It is expected that the number of generated clusters by the algorithm won't have an exponential increases by increasing the number of nodes. Because this method is designed based on max-Degree and in the previous sections its scalability has been discussed. It should be noted that the proposed algorithms will be used along with other applications such as routing. Unlimited increase in the number of clusters by increasing the number of nodes causes an increase in the volume of controlled data exchange and the drop of the performance parameters of the mentioned applications such as throughput.

Figure 3-14 shows the number of created clusters in the approach based on sustainability in the simulations with the number of different nodes. The related results have been compared with the methods of Max-Min, Degree, LCA and LCA2. As this is significant in the figure, the number of produced clusters in any of the simulation does not exceed from 31 and the drawn line slope is almost zero. This effect is visible in the other algorithms except LCA algorithm. LCA algorithm as is shown in figure produces cluster

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Has seen almost exponential according to the number of nodes in the system, produces clusters almost exponentially according to the number of nodes in the system. On the other hand, as we expected the lowest number of created clusters is for the max-Degree method. According to the method graph, we can conclude that this algorithm is scalable according to the number of nodes on the network.

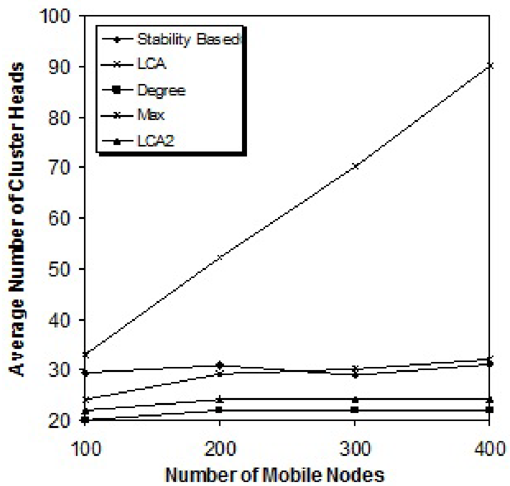
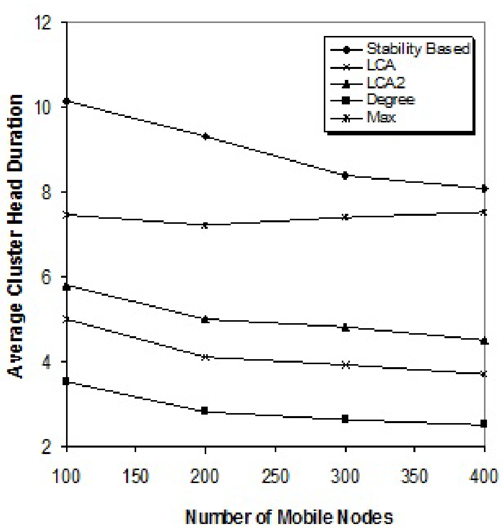


Figure 18 the average number of created clusters according to the number of nodes on the network.

- Cluster Head Duration (CHD)

This parameter is the sum of all the created heads lifetime divided by their whole number of them during simulation [4]. In figure 3-15 the resulted CHD in the algorithm based on sustainability and other clustering algorithms have been drawn and compared in the various simulations based on the whole number of nodes on the network. As it was expected, the worst CHD is related to the max-Degree method. All the methods of lowest-ID produce the heads with longer lifetime.

Figure 18 the average lifetime of the created clusters based on the number of nodes on the network.



This graph also shows CHD improvement in the sustainability-based methods compared to the all compared methods.

- Cluster Member Duration (CMD)

Figure 18 shows the extracted parameter in the algorithm based on sustainability in the comparison with other algorithms. Comparison between the extracted CMD in the algorithm based on sustainability and other algorithms shows that the improvement of this parameter in the algorithm based on sustainability.

Given that this parameter is a measure of clustering sustainability still the method of max-Degree has the weakest results.

Studying the effect of Connectivity on algorithm efficiency

In an Ad Hoc network that contains some mobile nodes, connectivity depends on the number of nodes on the network and the ranges of each node transmission (TX-Range). So to assess the effect of connectivity on the efficiency parameter of algorithms based on sustainability, we should study this algorithm with the TX-Range changes of the nodes on the network. In NS-2 a parameter that is called RXThresh is defined. By receiving each signal at the physical layer of a mobile node, if the signal strength is less than the defined amount, the received data in this signal is eliminated by the MAC layer; otherwise, they can be received correctly. This value determines our considered TX-Range for the mobile nodes. RXThresh value for any distance depends on the released model that is used in simulation. Another parameter that is called CSThresh is defined in NS-2 that is the determiner of the virtual sense ion the mobile nodes simulations as it was told in chapter 2. In order to assess the effect of connectivity on the algorithm efficiency parameters, a network with 100 mobile nodes in an area with the dimensions of 1200 ×1200 is considered. This network is stimulated with TX-Ranges of 20, 10, 50, 100, 150, 200, and 250 meters and with the maximum speed of 5, 10 and 20 (M/S) and considering the cessation time of zero. The length of entire simulation duration is considered 1000 seconds. The values of RXThresh and CSthresh used in the simulations are mentioned in the 3 table. The simulation parameters are provided in table 3.

Table 3 simulation parameters to assess the connectivity impact

TX Range(m)	RXThresh	Carrier Sense Range(m)	CSThresh
10	1.92278E-06	22	3.97269E-07
20	4.80696E-07	44	9.93173E-08
50	7.69113E-08	110	9.74527E-09
100	1.42681E-08	220	6.09080E-10
150	2.81838E-09	330	1.20312E-10
200	8.91754E-10	440	3.80675E-11
250	3.65262E-10	550	1.55924E-11

Figure 17 shows the effect of connectivity on the number of created heads in the network with the speed of 20 m/s.

As it seen in the figure, in a low TX-Range, connectivity in the network is so low that each node plays the role of a head and does not have any members. With the TX-Range increase the node are more placed in the scope of vision, and the clusters decrease to the extent that at 250 meter the average number of created clusters is 6 that is less than 10% of the nodes available in the network. Figure 3-18 indicates the effect of connectivity on CHD at the low speeds. As we have expected,

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the value of this parameter is greater at low speeds. Also at the very low connectivity this value gets closer to the total number of simulation time. However, at the high speeds and TX-Range of 250 meter, CHD is 50 seconds. In the next parts and by comparison with similar algorithms we will see that this is an acceptable number.

Table 4 simulation parameters to assess the connectivity impact

Max Speed	5, 10, 20 m/s
Pause Time	0
Total Simulation Time	1000 Sec
Number of Nodes	100
L×L	1200×1200
TX-Range	10, 20, 50, 100, 150, 200, 250m

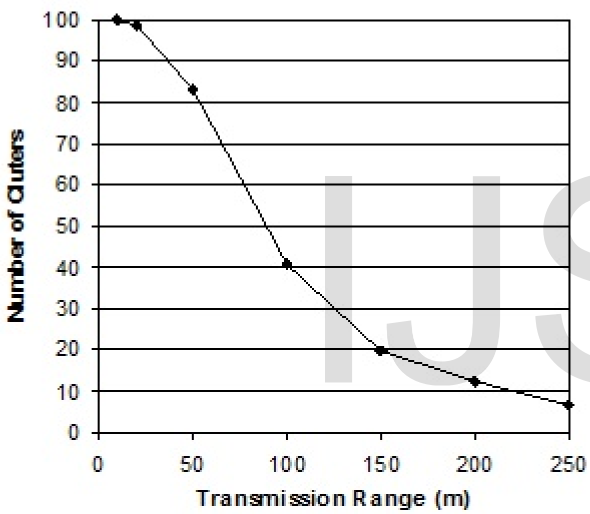

Figure 18 the effect of connectivity on the created clusters (speed 20 m/s).

As it seen in the figure, in a low TX-Range, connectivity in the network is so low that each node plays the role of a head and does not have any members. With the TX-Range increase the node are more placed in the scope of vision, and the clusters decrease to the extent that at 250 meter the average number of created clusters is 6 that is less than 10% of the nodes available in the network. Figure 3-18 indicates the effect of connectivity on CHD at the low speeds. As we have expected, the value of this parameter is greater at low speeds. Also at the very low connectivity this value gets closer to the total number of simulation time. However, at the high speeds and TX-Range of 250 meter, CHD is 50 seconds. In the next parts and by comparison with similar algorithms we will see that this is an acceptable number.

In figure 3-19 you see the effect of speed on CHD in TX-Range=250m. The effect is as we expected. The higher mobility of the nodes means the instability of the created clusters.

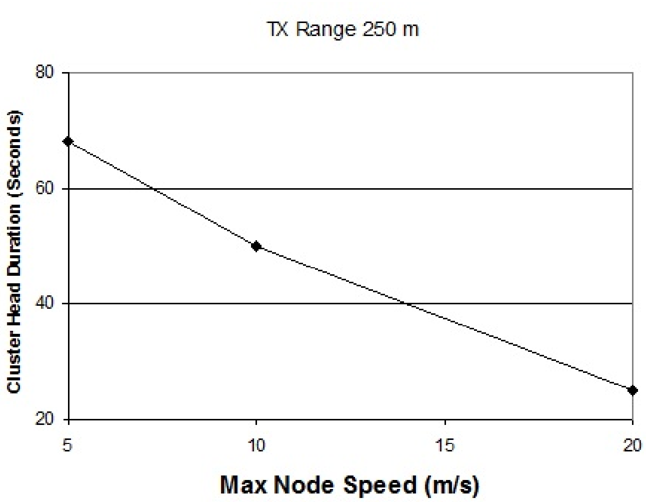

Figure 18 the effect of speed and connectivity on the clusters' lifetime.

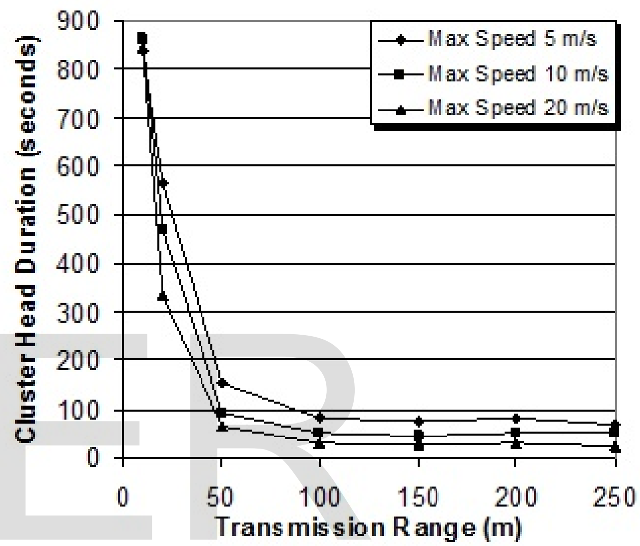

Figure 19 the effect of nodes speed on the clusters lifetime.

In order to compare the connectivity impact on the efficiency parameters, the algorithm based on sustainability was compared with LCC algorithm and MOBIC method. In the required simulations in this comparison, 50 mobile nodes in an environment with the dimensions of 1000 ×1000 were considered. The total length of simulation 900 seconds, and cessation time zero and the maximum speed was considered 1, 20 and 30 seconds based on [7].

Table 3-5 simulation parameters to compare with LCC and MOBIC

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In the figure 3-20 the effect of connectivity on the created clusters in each of the three algorithms is shown. Comparison between the results in this figure shows reduced number of clusters in algorithm based on sustainability in comparison with the two other algorithms in TX-Ranges of more than 50 meter. In this simulation, the maximum speed of nodes is considered 24 (m/s). As it can be seen in the figure, in TX-Range=250m the clusters are 10% of the whole available nodes in the network. In figure 3-21 the sustainability of the clusters has been investigated by the evaluation of the changes in the heads. This parameter is calculated by counting the number of heads that have lost their original role and have become just the member of another head. As this parameter is less, the system stability is more. Comparing the extracted parameter in the algorithm based on sustainability and other algorithms, in different connectivity and maximum speed of 20 (m/s) for the nodes shows the superiority of this parameter in the algorithm based on sustainability in the comparison with other algorithms. This comparison also has been implemented in TX-Range of 250 meter and with different speeds and the result of this comparison is shown in figure 3-22. As we can see in the picture, at the different speeds this algorithm was improved.

Table 5 simulation parameters to compare with LCC and MOBIC

Random Waypoint Parameters	
Max Speed	1, 20, 30 m/s
Pause Time	0
Total Simulation Time	900 SEC
Number of Nodes	50
L×L	1000 ×1000
TX-Range	10, 20, 50, 100, 150, 200, 250m

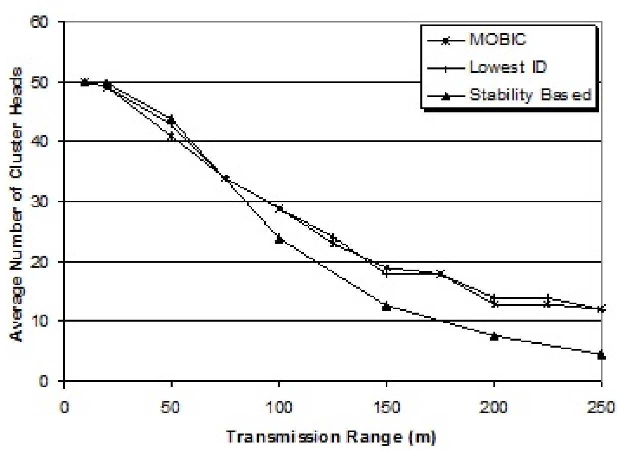

Figure 20 the effect of connectivity on the created clusters on the network at 20 (m/s) speeds.

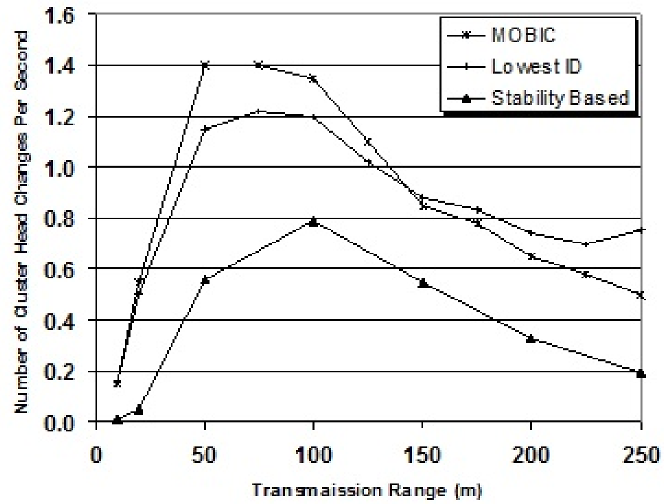

Figure 21the effect of connectivity on the clusters at 20 (m/s) speeds.

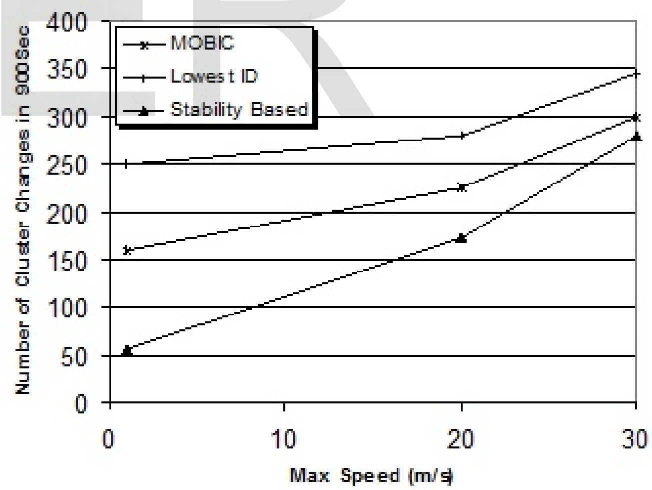

Figure 3-22 the effect of mobile nodes speed on the number of clusters changes (TX-Range=250m)

4 CONCLUSIONS AND SUGGESTIONS FOR FUTURE

In this study, we have considered the hierarchical routing and clustering as the two main components of this routing. In the clustering algorithms, extensibility and stability are taken into consideration. Extensibility is also proposed as the main parameter in other algorithms, but as it was told in the paper, in these algorithms sustainability is less considered. In this study, using clustering idea of the max-Degree type and presenting a method to improve the stability, we have achieved a scalable algorithm. In the third chapter with simulation we have shown that its sustainability is way better than the sustainability of the algorithms based on lowest-ID method. According to the presented results, the following things are offered to develop the research and using them in other areas is recommended:

In the clustering algorithm based on sustainability in this study, sustainability is considered as the most important parameters in optimization. In other words, the aim is that the nodes that are selected as cluster head maintain this responsibility as much as possible. As we have told, the greater stability of clustering improves the routing algorithms efficiency parameters based on clustering. But something else that should be considered is the limited resources in the available nodes in Ad Hoc networks. The thing that was considered so far was the limited capacity of the nodes as the most important limitation. Meanwhile, we should consider the power consumption limitation and computing power limitation. The nodes that serve as the cluster head during the routing and distribution of data has the main burden of data exchange within the clusters and between them. This leads to an increase in energy expenditure of the node and along with the long-term responsibility, the total energy of nodes will be lost. Thus, the adopting a process to shift the responsibility of the cluster head is needed. In other words, the responsibility over the time should be divided fairly between network nodes. In order to divide the clustering burden among the network nodes an appropriate parameter should be defined for optimization. The defined parameter should be an appropriate measure from the power consumption and computing power. The results presented in the previous sections show that the use of Beacon to exchange the clustering data is a suitable method that with an acceptable speed converge the transmitted data in the received nodes. As we have seen in the algorithm based on sustainability, neighborhood information and data related to sustainability are the information that was included in Beacon messages. Thus, a suitable ground is provided to send the clustering data in the algorithm based on the stability. So by defining an appropriate parameter for clustering load distribution, we can use this ground to send to other nodes. Only we should contain the considered parameters in the Beacon messages.

So far, most of the researches in the Ad Hoc networks were implemented by the simulation software. And few algorithms have analyzed the routing and clustering algorithms. This is due to the lack of mathematical models for describing mobility models and traffic patterns. The complexity of distributed algorithms used in these models is also another reason for the low number of analytical evaluations in this area. The provided mathematical analysis, still have enormous potential to be expanded.

Using clustering algorithms in the routing algorithm is another job that can be done. According to what has been done in this study, presentation and implementation of this algorithm is a complex work. With the definition of these algorithms we can assess the effect of clustering on the routing efficiency parameters such as delay in throughputs and data loss rate.

As it was told before, the discussion of routing based on guarantee of the quality of service (QOS) is one of the interesting issues for the researches for the Ad Hoc wireless networks. With clustering methods and distribution of data, access to a routing algorithm based on clustering to ensure quality of service is quite practical in the Ad Hoc Networks.

Given the tendency of researchers to undertake research in wireless sensor networks and due to some similarities between these networks and Ad Hoc wireless network, the provided routing and clustering methods for Ad Hoc wireless networks were investigated in wireless sensor networks. Evaluation of clustering algorithms presented in this study, in the wireless sensor networks can be considered as one of the future tasks.

REFERENCES

[1] 1- J. Y. YU and P. H. J. CHONG, "A Survey of Clustering Schemes for Mobile Ad Hoc Networks," IEEE Communications Surveys and Tutorials, First Quarter 2005, Vol.7, No.1, pp.32-48

[2] 2- Kaixin Xu,Mario Gerla, “A Heterogeneous Routing Protocol Based on a New Stable Clustering Scheme”, in Proceedings of IEEE MILCOM 2002, Anaheim, CA, Oct. 2002, pp.838-843

[3] 3- Prithwish Basu, Naved Khan, and Thomas D.C. Little, "A Mobility Based Metric for Clustering in Mobile Ad Hoc Networks", in Proc. Of IEEE ICDCS 2001 Workshop on Wireless Networks and Mobile Computing, Phoenix, AZ, April 2001, pp. 413-418.

[4] 4- A.D. Amis, R. Prakash, T.H.P. Vuong and D.T. Huynh. “Max-Min D-Cluster Formation in Wireless Ad Hoc Networks”, in Proceedings of IEEE INFOCOM'2000, Tel Aviv, March 2000, pp.32-41.

[5] 5- Rituparna Ghosh, Stefano Basagni, "Limiting the impact of mobility on ad hoc clustering," in Proceedings of the 2nd ACM international workshop on Performance evaluation of wireless ad hoc, sensor, and ubiquitous networks (PE-WASUN 2005), Oct 2005, Montréal, Quebec, Canada, pp.197-204.

[6] 6- p.Gupta and P.R. Kumar, “The Capacity of Wireless Networks”, in IEEE Transactions on Information Theory, vol. IT-46, no. 2, March 2000, pp.388-404.

[7] 7- Mohammed S. Al-kahtani, Hussein T. Mouftah, “Enhancements for clustering stability in mobile ad hoc networks,” in Proceedings of the 1st ACM international workshop on Quality of service & security in wireless and mobile networks (Q2SWinet'2005), Montreal, Quebec, Canada, Oct 2005, pp.112-121.