Performance of distributed clustering with weighted optimization algorithm for MANET Cognitive Radio

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***Abstract*-Mobile Ad-Hoc networks (MANET) are widely used for data communication between mobile nodes on the digital battlefield. Clustering has evolved as an important research topic in military MANETs in reference to supporting the ability of C4I system reconfiguration in highly dynamic operation. Clustering is a process that divides the network nodes into groups according to the command system. Each cluster has a Cluster Head (CH) as a coordinator within the cluster. For policy-based MANET Cognitive Radio (CR) it is very important to have an appropriate set of policies according to the variety of specific scenarios of the data network usage. A few algorithms have been recently studied and proposed for distributed clustering. The presented algorithm is based on the multi-criteria decision using the weighted function of the main network parameters. An appropriate selection of weights values for each particular scenario is critical for the effectiveness of MANET-CR. As the simulations have shown, the number of clusters within the network and the number of nodes in the clusters determine the ability of CR adaptation according to better usage of the available spectrum resources. The performances of the proposed algorithm has been evaluated through the simulations using OMNeT++ simulator and the results are encouraging.**

Keywords— MANET; Clustering Algorithm; clustering architecture; policy; management

I. INTRODUCTION

A Mobile Ad-Hoc Network is a dynamic multihop wireless network that is established by a group of mobile nodes on a shared wireless channel. The nodes are free to move randomly. The network's topology changes rapidly and unpredictably. Due to the limited transmission range of wireless network nodes, multiple network hops may be needed for one node to exchange data with another across the network. Nodes within transmission range can communicate directly with each other. Nodes outside the transmission range must communicate indirectly using a multihop routing protocol. Individual nodes are responsible for dynamically discovering the route. Instead, many clustering schemes have been proposed to organize the MANET into a hierarchy with a view to improve the efficiency of routing. The routing protocols can be divided into three categories: proactive, where each node periodically maintains one or more tables to store consistent and up-to-date routing information from one to every other node; reactive where the evaluation of routes is done only when it is necessary; and hybrid, which proactively maintains routes to the destination node within only a local network consisting of several neighboring nodes, generally referred to as a cluster, while reactively acquiring routes beyond the cluster.

The Mobile ad Hoc Network (MANET) topology is typical for the wireless communication without the infrastructure, in which the nodes are mobile, and the communication between nodes can be realized by other nodes with a few hops. For policy-based MANET Cognitive Radio (CR) it is very important to have an appropriate set of policies according to the variety of specific scenarios of the data network usage. On one hand it can be quickly reached if the jammers are used, on the another hand, it can be battery saving if the changes are very often.

II. CLUSTERING IN MANET

Clustering means a way to reconfigure all nodes into small virtual groups according to their regional vicinity and is defined as Cluster Head and cluster member that are determined according to the same rule. Every clustering algorithm consists of two mechanisms, namely cluster formation and cluster maintenance. In cluster formation, cluster heads are selected among the nodes to form clusters (see Figure 1).

Cluster Head is the node which manages the cluster activities such as managing cluster process, updating routing table, discovery of new routes. Except the Cluster Head, the other nodes inside the cluster are called Ordinary Nodes (ON).

Nodes having inter cluster links which can communicate with more than one cluster are called Gateway Nodes (GN). If the destination is inside the cluster, ordinary nodes send the packets to their cluster head that distribute the packets inside

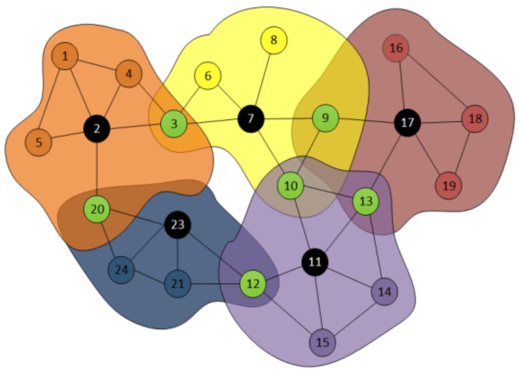

Fig. 1. An example of clustering architecture

the cluster; if the destination is other cluster, then the packets are forwarded to a gateway node.

In such way, only cluster heads and gateways take part in the propagation of routing update or control messages. This significantly reduces the routing overhead and also solves scalability problem in dense networks. The next phase of cluster maintenance comes into picture when there is the node movement. So, it needs to do re-affiliations among ordinary nodes and cluster heads. To avoid excessive computation in the cluster maintenance, current cluster structure should be preserved as much as possible

III. RELATED WORKS

Many clustering algorithms based on different optimization objectives (e.g. smallest ID, highest degree) have been proposed. In the article the authors will focus on the weighted clustering algorithms. The Weighted Clustering Algorithm (WCA) [1] is a combined weight metric-based clustering approach to form single-hop clusters. In WCA, a node which has the minimum sum of four indices is elected as the Cluster Head. To determine a Cluster Head, the algorithm considers the ideal number of nodes that a Cluster Head can handle, the sum of distances to other nodes in its radio distance, mobility and the time it becomes a Cluster Head.

The Efficient Management Algorithm for Clustering (EMAC) [2] utilizes factors such as the node degree, remaining battery power, transmission power, and node mobility for the cluster heads' election. It is based on the clusters' capacity and it uses the link lifetime instead of the node mobility for the maintenance procedure. Both EMAC and WCA assume that nodes know their location.

Another efficient weighted distributed clustering algorithm called CBMD [3] uses different weight function which takes into consideration the following parameters: connectivity (C), residual battery power (B), average mobility (M), and distance (D) of the nodes to choose locally optimal Cluster Heads. Advantages of this clustering algorithms include load balancing between the clusters, and smaller number of clusters formed by specifying the maximum and minimum number of nodes that a Cluster Head can ideally handle.

A Distributed Weighted Clustering Algorithm (DWCA) [4] works the same as WCA except that power management and distributed cluster set up is done by localizing configuration and reconfiguration of clusters. The consumed battery power is a better measure than the cumulative time during which the node acts as a Cluster Head that is used in WCA because it reflects the actual amount of power usage. If there is insufficient battery power, then the lifetime of topology can be increased by switching the role of the Cluster Head to an ordinary node.

In [5] the authors propose a scenario-based adaptive and distributed clustering algorithm SCAM (Scenario-based Clustering Algorithm for Mobile ad hoc networks).

A distributed algorithm based on (k,r)-dominating set is used for the selection of clusterheads and gateway nodes, where 'k' is the minimum number of CH per node in the network and 'r' is the maximum number of hops between the node and the CH. From among the 'k' dominating nodes, the non-clusterheads node can select the most qualified dominating node as its CH. The quality of the CH is calculated based on various metrics, which include connectivity, stability and residual battery power.

In [6] the authors propose a clustering technique for MANETs, which is distributed, dominating set based, weighted and adaptive to changes in the topology called Distributed Scenario-Based Diameter-Bounded Algorithm for Cluster Creation and Management in Mobile Ad Hoc Networks (DSCAM). This algorithm is similar to SCAM algorithm. After selecting CH, affiliation of other nodes with the clusterhead is decided based on the quality of CH, which is a function of connectivity, stability, residual battery power and transmission rate. The most qualified node is selected as its CH.

Service discovery architecture based on clustering is proposed in the Cluster-Based Service Discovery Protocol for Mobile Ad-hoc Networks [7]. It performs the cluster head selection by allotting a combined weight value based on the factors power level, connectivity and stability, intended for wireless mobile ad hoc networks. The proposed method permits switch-over of the service discovery messages only among the cluster members. It also considers the capabilities of the nodes for the distribution of workload.

IV. PROPOSED ALGORITHM

In this section we propose a clustering algorithm based on node degree, received power level, and remaining time battery. To describe this clustering algorithm in detail, we make the following assumptions, which are common in designing clustering algorithms for MANETs:

- The network topology is time-events model.
- Every message broadcast by a node can be received correctly by all its one-hop neighbours within a radio transmission range.
- Each node has an unique address and knows its fitness parameter.

The proposed clustering algorithm is two-stage procedure. The first stage is the nomination stage and the second one is the election stage. During the nomination stage, each node sending initial message in order to recon the environment and then it is calculating its fitness. The fitness (F) is the weight function of degree of the node (D_G), signal quality (S_Q) and battery level (B_L). This parameter is calculated using the formula:

$$F = D_G W_1 + S_Q W_2 + B_L W_3 \quad (1)$$

where W_1, W_2, W_3 are normalized weighting factors for the corresponding parameters:

$$W_1 + W_2 + W_3 = 1 \quad (2)$$

The flexibility of changing the weight factors helps us to apply our algorithm to various scenarios for MANET-CR [8].
To choose of weights values, the Elementary Error Functions are proposed. The possible choice of these values are presented in Figure 2, in which on the axis x some scenarios are pointed out as capital letters.

These function were used to establish the weight parameters in simulation scenarios described in Section V.

The next stage is election stage. During this stage, CH is selected, among the nodes with *NOMINATED* status. All possible states for each node in the proposed algorithm namely: *UNKNOWN*, *ORDINARY*, *GATEWAY*, *NOMINATED* and *SELECTED*, are shown in Figure 3.

The transition of a node is as follows:

- If the node has not received any message, it changes its status to *SELECTED* and becomes a CH.
- If the node has got the highest fitness parameter (self-nominated) or it has received nomination, it changes its status to *NOMINATED*.
- If the node has received a message that CH is selected, it changes its status to *ORDINARY*.
- If the node is within transmission range of two CHs, it changes its status to *GATEWAY*.
- If the node is a gateway node and has not received any message from one of the two CHs, it changes its status to *ORDINARY*.

V. SIMULATION SCENARIOS

The impact of the simulation parameters for the performance of the algorithm is shown in the Table I.

As we can see, the degree of the node parameter for stationary nodes has a higher impact in contrast to mobile nodes. In the stationary network topology, the number of neighbours can be assumed as constant. In this case, the node which has the biggest number of neighbours should be the CH. On the other hand, when the nodes are mobile, the network topology and number of neighbours are changed. In this case, the degree of the node has smaller impact on the fitness function. In our opinion, signal quality parameter has medium impact in both cases. This parameter depends not only on the network topology changes but also on the environment where nodes are working (e.g. urban, suburban). For example, if we highlighted signal quality parameter in the topology, where all nodes are stationary and distributed in the urban environment, it may lead it to a big number of created clusters. The battery level parameter has a smaller impact on stationary topology, where we are able to connect to a power supply. This parameter has a high impact where nodes are moving and the battery is the only source of power.

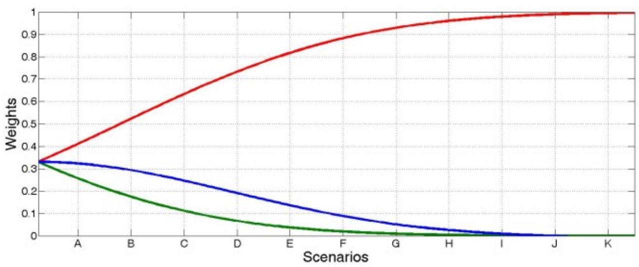

Fig. 2. Functions for selection of weight values

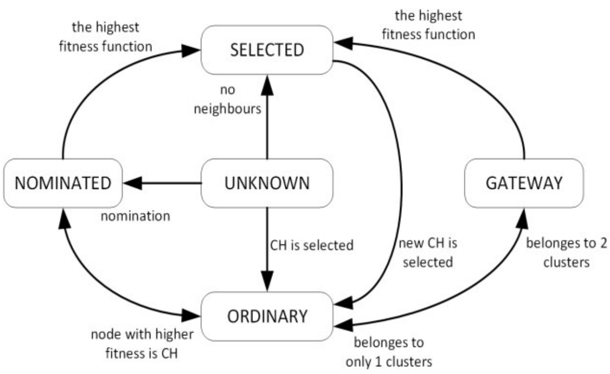

Fig. 3. The transition diagram for each node state

VI. SIMULATION RESULTS

Proper selection of the weights is important in the creation of the network structure. Having an impact on the number of created clusters and nodes in the cluster, we can increase the efficiency of the network. Therefore, the purpose of these tests is to observe the impact of various weighted parameters on the number of created clusters. All simulations have been performed using discrete event simulation environment, OMNeT++, ver. 4.2.

A. First scenario parameters

In Figure 4 the example of network structure is presented.

For the first test in this scenario, we assumed that every node has the same chance to act as a CH and all weights are equal. In the second test, we change the weight parameter according to the scenario, to find the best value, which allows us to optimize the clustering algorithm for MANET cognitive radio. The parameters for both tests are shown in Table II.

B. First scenario results

The average number of created clusters can be seen in Figure 5. For a better comparison, two curves are shown in the Figure. As we can observe, the highlighted weight for the degree of the node, reduces the number of created clusters (green curve). A smaller number of clusters enables better management of the network. This is also important when the number of set of frequency resources is small.

TABLE I. IMPACT OF THE SIMULATION PARAMETERS

Parameter	*Stationary nodes*	*Mobile nodes*
Degree of the node	high	small
Signal quality	medium	medium
Battery level	small	high

TABLE II. SIMULATION PARAMETERS

Parameter	***Value***	
Network area	1000x1000m	
Number of nodes	10-80	
Transmission range	240m	
Weight parameter	***Test 1***	***Test 2***
Weight 1 (D_G)	0,33	0,70
Weight 2 (S_Q)	0,33	0,30
Weight 3 (B_L)	0,33	0,00

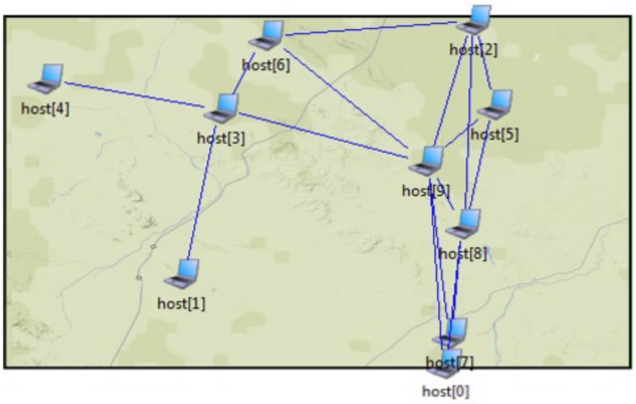

Fig. 4. The example of stationary network structure

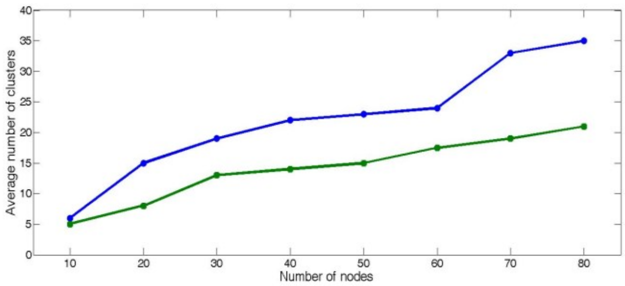

Fig. 5. Average clusters number vs. nodes number in first scenario (blue color: before changing parameters; green color: after)

C. Second scenario parameters

In Figure 6 the example of network structure is presented.

In this scenario the number of stationary nodes is the same as the number of mobile nodes. For example, the number of nodes equal 10 means that there are 5 stationary and 5 mobile nodes in the network. In that kind of network, the structure changes very often. We have two kinds of nodes (stationary and mobile) so finding the effective weights value is difficult. For this purpose, for every group of nodes, the simulation tests were performed 5 times. This allowed us to determine the average values. In the first test all weights are equal. During the second test we change the weights parameters, to find the best value, which allows us to optimize the clustering algorithm. The change of weights parameters depended on the type of nodes. The parameters for both tests are shown in Table III.

D. Second scenario results

In Figure 7 we can see the results of this experiment. For a better comparison, two curves (before and after changing the weights) are shown in the same figure.

For a small number of nodes, the results are very similar. Greater difference can be observed with the increasing number of nodes. For example, before changing the weight parameters according to the type of nodes for 80 nodes we arrive with approx. 35 clusters in the network. Is a very huge number and the management of this network is difficult. This number is also unfavourable when there is a small number of available frequency resources

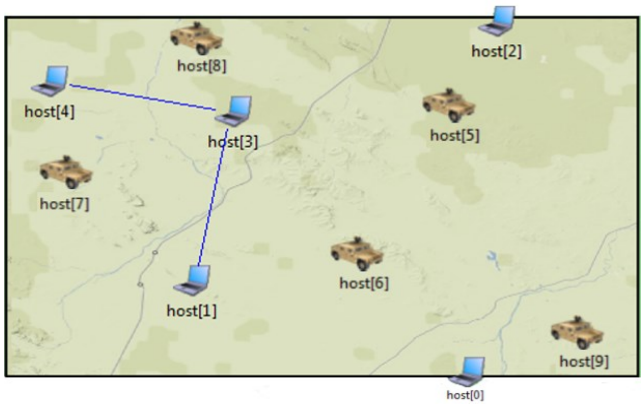

Fig. 6. The example of mixed network structure

TABLE III. SIMULATION PARAMETERS FOR STATIONARY NODES

Parameter	***Value***			
Network area	1000x1000m			
Number of nodes	10-80			
Transmission range	240m			
Speed for mobile nodes	1-10m/s			
Weight parameters	***Test 1***		***Test 2***	
Type of nodes	stationary	mobile	stationary	mobile
Weight 1 (D_G)	0,33	0,33	0,70	0,10
Weight 2 (S_Q)	0,33	0,33	0,22	0,25
Weight 3 (B_L)	0,33	0,33	0,08	0,65

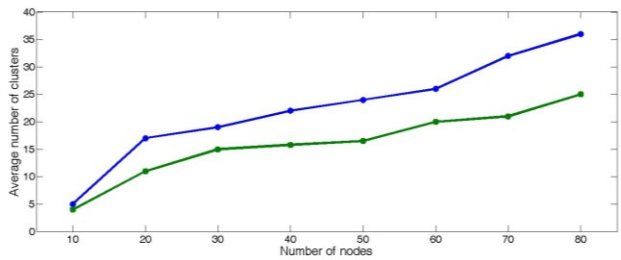

Fig. 7. Average clusters number vs. node number in second scenario (blue color: before changing parameters; green color: after)

VII. CONCLUSION

Based on the results, it can be concluded that it is possible to determine the optimum weight values for nodes depending on the adopted policy management for different scenarios of the network operation. When using automated procedures, automation of learning and decision-making method can be used in MANET Cognitive Radio. The results obtained will also allow to develop a set of policies that are needed to manage the cognitive radio network. This makes it possible to maintain efficient and stable topology in MANET-CR environment.

The simulation results obtained are original. Currently in the literature there is a lack of a suitable algorithm, the results of which can be compared with the results described in this article. To determine the average values for each group of nodes, simulation tests were performed five times. Each time the nodes were randomly distributed in the same physical area but with different positions. This enables the use of optimization algorithm in various scenarios of MANET-CR.

Presented procedure was elaborated and examined in the European Defence Agency project CORASMA (Cognitive Radio for Dynamic Spectrum Management), contract number B-781-IAP4-GC [9].

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