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# Quality of Clustering in mobile Ad Hoc networks

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**Abstract**

We consider the problem of appropriate clusterhead selection in wireless ad-hoc networks where it is necessary to provide robustness in the face of topological changes caused by node motion, node failure and node insertion or removal. The main contribution of our work is a new strategy for clustering a wireless AD HOC network and improvements in WCA and other similar algorithms. We first derived some analytical models and thereafter some clustering schemes. Our contribution also extends previous works in providing some properties and analyses of Quality of Clustering (*QoC*) in AD HOC. We showed that our algorithm outperforms the Weighted Clustering Algorithm (WCA) in terms of cluster formation and stability. One of the main ideas of our approach is to prioritize favourable nodes in clusterhead election and re-election processes. We strived to provide a trade-off between the uniformity of the load handled by the clusterheads and the connectivity of the network.

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*Keywords:* ad hoc networks, clusters, load balancing, stability;

## 1. Introduction

Ad hoc networks are wireless, infrastructureless, multi-hop, dynamic networks established using a collection of mobile nodes, providing significant features to the modern communication technologies and services [1]. In ad hoc networks, clustering is an important technique to divide the large network into several sub networks. Cluster-based architectures effectively reduce energy consumption, and enable efficient realization of MAC and routing protocols, security mechanisms and data aggregation. A cluster is a group of interconnected nodes with a dedicated node called a clusterhead (CH). CHs are responsible for cluster management, such as scheduling the medium access,

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dissemination of control messages, or data aggregation [2]. Therefore, the role of the CH is critical for proper network operation. Failure of a CH results in expensive CH re-election and re-clustering operations [2].

A weight based distributed clustering algorithm (WCA) which can dynamically adapt itself with the ever changing topology of ad hoc networks was proposed in [3]. In this approach, the number of nodes to be catered by a cluster head is restricted, so that it does not degrade the MAC functioning. It also has the flexibility of assigning different weights and takes into account a combined effect of the ideal degree, transmission power and mobility battery power of the nodes.

In [4], to minimize the waste of signals, power and bandwidth, the authors propose a modified algorithm that uses WCA for cluster formation and mobility prediction for cluster maintenance. They propose to reduce the overhead in communication by predicting the mobility of nodes using linear auto regression and cluster formation.

In [5], using a heuristic approach, the authors give some interesting equations for the cluster density and cluster order of homogeneously distributed nodes running the DMAC algorithm [6]. Since the DMAC structure is unique, the equations also hold in a mobile scenario if the mobility model used retains a homogeneous distribution of the nodes. If the nodes are not homogeneously distributed, the cluster density will decrease.

In [7], the authors introduced a new type of algorithm called Enhancement on Weighted Clustering Algorithm [EWCA] to improve the load balancing and the stability in the MANET. The cluster head was selected efficiently based on factors like high transmission power, transmission range, distance mobility, battery power and energy. Since the cluster head will not be changed dynamically, the average number of cluster formations will be reduced.

In [1, 3, 6, 7, 8, 9], we observed that all nodes have the same chance to participate in the CH selection process, which affects the quality of the formed clusters. The motivation for the present work is to prioritize only some favorable nodes in this process. Consequently, we introduce our analytical models to overcome the previous inefficiencies.

In the remainder of this paper, Section 2 problem specifications are presented. Our algorithm analytical models are given in Section 3. Section 4 illustrates our clustering quality. The formal definition of our algorithm and its illustrative example are given in Section 5. Conclusions are given in Section 6.

## 2. Network model and problem specifications

As defined in [3], the network formed by the nodes and the links can be represented by an undirected graph $G = (V, E)$, where $V$ represents the set of nodes $v_i$ and $E$ represents the set of links $e_i$. Note that the cardinality of $V$ ($|V|$) remains the same but $|E|$ always changes with the creation and deletion of links. Clustering can be thought of as a graph partitioning problem with some added constraints. As the underlying graph does not show any regular structure, partitioning the graph optimally (i.e., with minimum number of partitions) with respect to certain parameters becomes an NP-hard problem [10]. The neighborhood $\Gamma(v_i)$ of a CH $v_i$ is the set of nodes which are directly linked to it and which are in fact the nodes lying within its transmission range ($R_{v_i}$). This defines the degree of the node $\boldsymbol{v_i}$:

$$\Gamma(v_i) = \{v_j,\ such\ that\ \ dist(v_i, v_j) < R_{v_i}\} \quad (1)$$

where $dist(v_i, v_j)$ is the measured average distance between $v_i$ and $v_j$. Similar to [3], when a system is initially brought up, every node broadcasts its id which is registered by all other nodes lying within *its* transmission range. It is assumed that a node receiving a broadcast from another node can estimate their mutual distance by measuring the ratio of receiving power and transmission power. The node degree of a node $v_i$ is deduced as the cardinality of the set $\Gamma(v_i)$:

$$deg(v_i) = |\Gamma(v_i)| \quad (2)$$

More formally, we are looking for the set of vertices $S \subseteq V(G)$, such that the union of $\Gamma(v_i)$, where $v_i \in S$, forms $V(G)$. The set $S$ is called a *dominating set* such that every vertex of $G$ belongs to $S$ or has a neighbor in $S$. To meet the requirements imposed by the wireless mobile nature, a clustering algorithm is required to partition the nodes of the network so that the following ad hoc clustering properties are satisfied [6]: (a) Every ordinary node has