

A survey on Trust and Reputation-Based Clustering Algorithms in Mobile Ad-hoc Networks

Masood Ahmad¹, Abdu Salam², Ishtiaq Wahid³

¹ Lecturer, Department of Computer Science, Abdul Wali Khan University Mardan.

² Assistant Professor, Department of Computer Science, Abdul Wali Khan University Mardan

³ Lecturer, Department of Computer Science, Abdul Wali Khan University Mardan

ABSTRACT

In flat mobile ad-hoc MANETs, an extensive amount of information is produced that may saturate the network. Due to network scalability and node heterogeneity, it is highly desirable to organize the nodes into clusters and form a hierarchical structure. Cluster formation in ad-hoc wireless MANETs has been a problem from a long time. Recent work on clustering in MANETs focus on balance cluster formation, but there is always a tradeoff in network division quality and cluster formation time. Some nodes reveal false information during the clustering process that may result unstable clustering structure. One method to form high quality clusters is to consider the trust and reputation of mobile nodes during network operations. In this paper, a comprehensive survey of reliable, trust and reputation based clustering algorithms is presented. The clustering algorithms are classified objectives, and some other metrics. The trust and reputation based clustering algorithms are summarized. The objectives and findings of all papers under consideration are stated. The future challenges of these algorithms are also highlighted to help the young researchers in conducting their research on clustering. The research directions are highlighted in the field of clustering in MANETs.

Keywords: Ad-hoc wireless networks, Node heterogeneity, Cluster formation,

Author's Contribution

^{1,2} Manuscript writing, Data analysis, interpretation and Active participation in data collection

³ Conception, synthesis, planning of research, Interpretation, and discussion

Address of Correspondence

Masood Ahmad
Email: masood@iqraisb.edu.pk

Article info.

Received: Dec 13, 2017
Accepted: May 07, 2018
Published: June 30, 2018

Cite this article: Ahmad m, Salam A, Wahid I. QoS A survey on Trust and Reputation-Based Clustering Algorithms in Mobile Adhoc Networks. J. Inf. commun. technol. robot. appl.2018; 9(1):59-72.

Funding Source: Nil
Conflict of Interest: Nil

INTRODUCTION

Mobile ad-hoc MANET is the group of nodes that are able to communicate with each other using wireless link multi-hop communication mechanism [1][12]. In these types of networks, there is no fixed or stationary infrastructure. Every node in the network forwards their own packets as well as the packets coming from other nodes in the network. The development of a network

routing protocol, which can find the best routes between communicating nodes for the mobile ad-hoc network is one of the hottest research issue. The network topology often changes when the nodes move from one place to another, so the routing protocol should be able to accommodate these changes efficiently. In flat routing mechanism huge amount of excessive information is

produced and may saturate the ad-hoc wireless network if the network size is very large [3]. Additionally, there may be heterogeneous nodes in the network, which assumes variable resources. These nodes form internal hierarchy in the network based on their roles. Ad-hoc network functions such as routing are supported easily if the nodes occupy powerful batteries have long communication ranges and high computational power than the nodes in ordinary MANET.

One solution that addresses the problem of node heterogeneity and confines the amount of information is broadcasted inside the network is the use of cluster-based routing mechanism [36]. In cluster based routing the network nodes are grouped into overlapping subparts known as clusters [52]. Unlike flat based routing (the paths are recorded between nodes), in cluster-based and routing, a paths are recorded between the clusters which make the hierarchy of the network. Thus, the control messages that are produced due to routing overhead are decreased and the network lifetime is increased. The node that acts as a representative node in a cluster is known as a cluster head (CH). The CH manage all the activities carried out within the cluster and also exchange information with other clusters. All other nodes in the cluster have direct access to the representative node, i.e. CH and to some other nodes known as gateways. Gateways are the type of nodes which are in the communication range of two or more clusters.

In this paper, the clustering schemes are classified based on objectives and a comprehensive survey of trust and reputation based clustering algorithms are presented. The contributions of this work are:

- We acknowledge the most important parameters that need careful attention during the clustering formation process in mobile ad hoc networks.
- We classified the most recent clustering algorithm in mobile ad hoc networks.
- The trust and reputation based clustering algorithms are summarized.
- The objectives and findings of each algorithm under consideration are presented.
- A summary based on clustering quality is presented in tabular form.
- Future directions for the young researchers are highlighted.

The rest of the paper is structured as follows: Section II discusses the clustering in mobile ad hoc networks, in Section III, the clustering algorithms are classified based on objectives, in Section IV, the trust and reputation based clustering algorithms are summarized and their objective, limitations and future directions are discussed. Finally, the paper is concluded in section V.

CLUSTERING IN MOBILE AD-HOC NETWORK

A. What is clustering?

The process of dividing the ad hoc network nodes into nonoverlapping virtual groups is known as Clustering [51]. The assignment of nodes to a cluster group is based on some rule. The mobile host's behavior within a cluster will be different from the mobile hosts outside the cluster. The nodes in a cluster are also classified based on its function such cluster head, cluster member, or gateway node. The duty of a cluster head is to organize the cluster members, handle inter-cluster communication, data transmission to the base station and so on. The gateway node falls within the jurisdiction of two or more cluster heads. The responsibility of the gateway node is the transmission of data between two cluster heads. The member node often called ordinary node, it's neither a cluster head nor gateway node.

B. Clustering Parameters

It is of great importance to write about some key parameters with respect to the whole clustering process before categorization of the clustering algorithms in mobile ad hoc networks. Furthermore, these parameters can also be utilized for comparison of the clustering algorithms under consideration throughout this paper.

Number of clusters -The current work on clustering in MANET mainly focus on cluster formation and cluster head selection that leads apparently to different number of clusters. The number of CHs is known in advance in some papers and therefore, the number of clusters is determined in advance. Additionally, the cluster count is the most critical parameter with respect to efficiency.

Intracluster communication – in some clustering architectures, the direct or one hop communication within the cluster heads and its members are assumed. But multi-hop communication is frequently required in situations such as the transmission range of node in

MANETs is short or the number of cluster heads is bound to some threshold or the number of nodes in a cluster are large.

Mobility - stable clusters are formed when the mobile nodes installed in the field are static in nature and the inter-cluster and intracluster network will be managed efficiently. Alternatively, when the nodes in the network or cluster heads are mobile, the membership of nodes should change dynamically, imposing clusters to change over time and possibly need to be regular maintenance.

Nodes types and roles – the cluster heads in heterogeneous MANETs are assumed to be a high computation and communication nodes while in homogeneous ad hoc networks, the computation power like the energy of all nodes are same. An ordinary node can play the role of cluster head that may be selected based on some criteria.

Cluster formation – the clusters should be formed in a distributed manner when time efficiency will be the key criteria. Recent work on clustering focus on the distributed nature of cluster formation in which the cluster formation task is assigned to multiple nodes in the network. The earlier schemes, emphasis on the centralized cluster formation in which a central coordinator node is responsible to manage the cluster formation process.

Cluster head selection - in heterogeneous mobile ad hoc networks, the cluster heads are known in advance as high power and high communication nodes are the best candidates for cluster head's role. In some algorithms, the cluster heads are selected randomly based on a probabilistic manner or on some criteria (like communication load, connectivity index, energy, mobility, etc.).

Algorithm complexity – the fast execution of the clustering algorithm is the design goal of most recent clustering schemes. Thus, for most algorithms proposed currently, the time complexity or convergence rate is constant or depends on the number of cluster heads. In earlier schemes, the time complexity depends on the number of nodes in the MANET.

Multiple levels - to evenly distribute the energy consumption of mobile nodes in the ad-hoc network, the nodes are grouped in a hierarchal fashion with multi hierarchy. The multi-level clustering architecture has great influence when the communication between cluster heads

is very important in a large size network.

Overlapping – to achieve the routing efficiency, some researchers focus on overlapping clusters for quick execution of the clustering algorithm. Most of the famous schemes, emphasis on non-overlapping cluster formation or minimum overlap.

C. Design Goals of Clustering

Mobile ad hoc network implementation offers a huge challenge that cannot be met merely by the design goals of conventional or traditional networking applications [36]. Clustering algorithms are vital to the structure and configuration if the aim is to make an invisible global setup is always to be understood where mobile nodes can communicate with each other reliably, efficiently, effectively and wirelessly without loss of connectivity, data or massive volume of energy consumption.

Cost of Clustering - Clustering plays a vital role in designing a network topology, but some necessary processing and communication are required to form clusters and maintain it when a topology change occurs. Communication is more costly than data processing and transmission. More bandwidth will be required when the size of the network becomes larger as the communication loads rise with network size.

Load Balancing - The cluster heads are responsible to collect the data from their members and communicate them with other clusters. It is highly desirable to evenly distribute the nodes amongst the clusters to balance the load without compromising the projected performance goals. The formation of equal size clusters prolongs the lifetime of the network and energy consumption is also minimized. Balance clusters have a strong influence on data delay [37].

Clustering Formation - The formation of clusters in mobile ad hoc networks needs careful attention as different applications have different priorities regarding node arrangement, the cluster size, cluster head selection and the parameters for the style of configuration [38].

Real-time Operation - Some applications require quick transmission of data from source to a destination such as emergency services, applications or military tracking [39]. In some applications, the delay in data transmission does not compromise the design goals of the network. While designing a clustering algorithm, the delay created during cluster formation and maintenance

must be considered depends on the application requirements.

Maximizing Network Lifetime - In some applications, the energy constraint of nodes has a strong influence on the network lifetime. In cluster network architecture, the node having sufficient resources are selected as cluster heads and it is very important to minimize the energy consumption of inter-cluster communication by placing the cluster heads close to nodes in their cluster [40] if possible. Another method used is to combine the cluster formation and communication in order to increase the lifetime of the network [41].

Maintenance Mechanisms - Due to node mobility, interference, node death and nomadic nature of some nodes, the link failure may occur in mobile ad hoc networks. The clustering algorithms must have a mechanism for link recovery in order to reestablish the connection failure.

Connectivity and Reduced Delay - When the cluster heads are selected from the network nodes based on a criteria other than long communication range like satellite link nodes, the connectivity between clusters must be ensured in various applications. The establishment of direct communication paths from CH-CH ensures the connectivity goal for broadcasting messages [42]. In clustering architectures, some nodes play the role of cluster heads, the virtual backbones are achieved in the form of a subgraph via connected dominating subsets. Inter-cluster connectivity requires careful attention when the quick transmission is required with minimum latency is concerned. K-hop clustering is a K-dominating set problem [43].

Quality of Service (QoS) - The researchers in [44] that mobile ad hoc network perform efficiently when some nodes are selected randomly from the network to form the virtual backbone to transfer control messages for service discovery among selected nodes. The quality of service is better achieved by dividing the network into sub-networks called clusters. The network lifetime is increased with a clustering approach.

D. Advantages of Clustering

When the number of nodes in a mobile ad hoc network is very large, the clustering structure guarantees efficient performance. Clustering architecture is very beneficial in mobile ad hoc networks. Some benefits are:

Aggregation of Topology Information - The clustering mechanism support the aggregation of topology information as the number of nodes in the ad-hoc network larger than the number of nodes in a cluster. Hence, the node only stores information about a small portion of the network, i.e. the cluster to which a node belongs [45].

Efficiency and Stability - The noteworthy feature of a cluster architecture is; it causes a network to look stable and smaller in the eyes of each mobile node. When a node moves from one cluster to another cluster, the nodes in the former and new cluster only need to update their data structures locally [46][47] about the topology changes and the whole network is not disturbed.

Reserve bandwidth - The inter-cluster communication is limited to, cluster heads and in some cases the gateway nodes, thus, the number of message exchanges between mobile nodes are restricted to preserve communication bandwidth.

Routing Efficiency - The nodes in the flat structure take the responsibility of a router hence, data so routing overhead messages are increased to find an efficient path from source to destination. The MAC layer reduces the overhead messages up to some extent. To make the routing process easier and reduce the routing overhead messages, cluster architecture is the solution [48].

Spatial Reuse of Resources - In the clustering structure, the non-overlapping clusters can reuse the same frequency at the same time. The clustering structure can also decrease collision. The bandwidth is less utilized and can be used for some useful purpose [49].

HOW TO CLASSIFY CLUSTERING SCHEMES?

Cluster-based algorithms in MANETs can be classified in many ways. It may be classified as zone based [30] clustering, or multi-hop [20] [21] clustering transmission range or one hop [5] [7] clustering and signal strength based [13] clustering. The mobility metric is very significant in mobile ad hoc networks and the MANETs can be classified based on a mobility model such as group mobility [1] [6], regular [5] and random mobility [8] [9] [12] [16] [17] [19] [20] [21]. The nature of the events that take place in MANETs have a strong impact on clustering process and thus the clustering can be

classified into proactive [1] [5] [6] [8] [9] [11] [12] [16] [17] [19], reactive [7] [10] [13] [14] [15] [18] clustering and hybrid [33] clustering. In the same way, the nodes of the network can be grouped based on the size of the cluster such as fixed [1] [5], balanced [14], unbalanced [34] and dynamic or random [20] [21] partition. In cluster based routing, each cluster may have a cluster head so the cluster based routing can be classified based on availability of cluster heads [1] [5] [6] [7] [8] [9] [13] [14] [15] [17] [18] [19] [20] [21] and the cluster heads criteria not defined or having no cluster heads [10] [11] [12] [16]. Clustering can be classified based on cluster head selection criteria such as node degree [5] [8] [13] [14] [17] [18], remaining energy [7] [8] [15] [17] [18] [19], trust value [22] [27], mobility [5] [6] [7] [13] [15] [17] [18] and predefined cluster heads [1].

Clustering protocols can be generally classified into five categories. First, in connectivity based clustering [5] [8] [13] [14] [18] [21], the clustering can be formed based on the degree of the cluster head. Usually, the nodes with the highest connectivity are selected as cluster heads. Second, the cluster is formed based on the mobility of the nodes such as in mobility aware clustering [5] [6] [13] [15] [18] [19] [20]. Here, it is important to mention that the nodes with relative mobility to their neighbors are the best candidates for cluster heads. The relative and in some cases the future mobility should be considered during cluster formation. Third, another important metric that should be considered is the remaining energy of the nodes while selecting cluster heads. So energy aware clustering [7] [8] [14] [15] [17] [19] [20] are proposed. Fourth, the nodes reputation and trust should be considered during the clustering process. Trust and reputation based clustering [8] [11] algorithms are discussed in the literature. Reputation-based clustering mechanism is necessary to prevent selfish nodes from unwanted behavior. Last, some researcher uses multiple while forming clusters. In Hybrid routing [31] [5] [7] [8] [13] [14] [15] [17] [19], all the metrics such as node mobility, remaining energy, trust value, and connectivity or few matrices are considered.

In this survey, the clustering schemes are classified based on the objective and the technique used to obtain the objective. Evolutionary algorithms based clustering [3] [14] [17] [29] are used to form optimized clusters. The

protocols that work on special scenarios with group mobility and are mobility based clustering [1] [18]. To prolong the network time and decrease the energy consumption, energy efficient [7] [10] [12] clustering techniques are proposed. To distribute the load on the whole network, load balancing [30] [2] [3] based cluster formation techniques are discussed. To avoid the selfish behavior of nodes during cluster formation and communication process, cooperative and Trust based clustering [8] [11] techniques are explained. Another AI technique to form optimal clusters in MANETs, Swarm intelligence and PSO based clustering [4] [16] [2] are discussed and criticized. Mobility has a very strong impact on topology maintenance. Both the cluster heads and member nodes can move from one cluster to another cluster area. So, mobility aware and stable clustering [5] [6] [13] [20] is considered and critically reviewed. Similarly, in MANETs topology changes very frequently due to nodes mobility. To reduce topology changes, stable clusters are formed with less re-affiliation. To decrease the topology maintenance overhead stable clustering [21] schemes are discussed. A dominated set of cluster heads are formed and the neighbors near to a cluster head node joins the cluster and are proposed in distributed dominated set and ring clustering [6] [18] [26]. data replication based [25], Top-k query routing [23] [24], redundant broadcast, path discovery [19] and QoS based Clustering [9] are other algorithms proposed in this area. The next section explains in detail the trust and reputation based classification scheme, its objectives, limitations and other useful properties are summarized.

RELIABLE, TRUST AND REPUTATION BASED CLUSTERING

In mobile ad hoc network, some ordinary nodes play a selfish role to decrease its communication workload. The services should be granted based on the contribution of the node in network functioning. The nodes with a good reputation have better chance to avail the network services and the network services are denied from nodes having bad reputation. The reputation of a node can be computed by its contribution during network functions. So a great contribution means a good reputation. To address the issue of selfishness and reliability of nodes, this section explains the trust and reputations based clustering

techniques. A summary of clustering metrics assumed is presented in table 1 and simulation related data are summarized in table 2.

A. Reputation-based Clustering OLSR Protocol [8]

In this paper, the robustness and reliability are taken into account in the presence of selfish nodes to increase the lifetime of the network. The proposed scheme is based on demand link state routing. The reliability of a mobile ad hoc network can be accomplished by the selection of most trusted paths for routing information. To prolong the lifetime of the network, the number of relay nodes that broadcast the control messages should be decreased. The residual energy of the nodes should also be considered during the relay nodes selection process. This paper emphasis on a relay node election and clustering algorithm called HOLSR based on node residual energy as well as the degree. The improved form of OLSR packets is utilized to select the relay nodes and cluster heads. The scheme also considers the existence of selfish nodes in the network. The selfish nodes are getting benefits from other nodes and are not cooperating in network functions. Therefore, an incentive mechanism is used that attract the selfish nodes to act fairly during the course of the election process. The reputation of the nodes can be computed by the incentives received during the cluster construction process. The network services are granted to nodes based on nodes reputation. In this fashion, all the nodes must cooperate in order to receive extra network services. The most trusted paths are defined by the number of trusted nodes in the transmitting route. This model is known as reputation-based hybrid on-demand link state routing algorithm.

Different clustering schemes are studied to increase the lifetime of the network, guarantee the contribution of selfish nodes by incentives and guarantee the reliability of the network under consideration by the most trusted paths election. The cluster heads are elected based on the degree of the nodes, the residual energy of the nodes or both.

An incentive compatible or truthful technique has to be inducted to encourage the neighbors to cooperate and reveal fairly their private information. In this manner, the cooperative nodes will get more services than the selfish nodes. The technique used in VCG [50] is assumed to motivate the nodes for cooperation. The leading approach

for ordinary nodes is to cooperate so as to build their reputation and the nodes can obtain some services if the services in the network are granted in relation to nodes reputation. After the election of cluster heads and relay nodes, the network is divided into different clusters. The next task is to identify the most reliable paths for data transmission. The routes are identified based on the relay nodes reputation for robustness and reliability.

Objectives [8]	(i) Residual energy level and connectivity index is used for selection. (ii) The relay nodes are reduced which results in a few topology control messages. (iii) The percentage of multipoint relay (MPR) nodes is decreased. (iv) Offers reliability and robustness through the selection of paths. (v) An encouragement cooperative system that enhances the reputation of cooperative nodes. (vi) The nodes are motivated to collaborate during cluster formation and MBR selection process.
Findings	(i) The nodes mobility is not considered during cluster formation and a highly mobile node may be elected as a cluster head in slow networks and a node with low mobility may be elected high speed MANETs. (ii) The neighborhood of nodes is not defined. (iii) Node quality in terms of its neighbors is not defined. (iv) The paths are selected based on its reputation, shortest paths may not be selected for forwarding the packets that decrease network lifetime.

B. An efficient reliable one-hop broadcast [11]

The focus of this research is to explore many concurrent executions of the communication to achieve efficiency and assure one hop trustworthy broadcast. The algorithm works on the MAC layer. The packets collision in control packets is also reduced in the proposed scheme and the network throughput is improved with simultaneous communication. Broadcast in progress (BIP) control packet is utilized to achieve one hop reliable broadcast for preventing a collision. A unique bit pattern is used in BIP that distinguish it from other control packets. The data packets comprise extra information like source ID, packet ID data packet size, along with original data. In this method, three different channels are used to make simpler the collision prevention process and the

probability of the collision should be decreased. Control packets are transmitted through the BIP channel and the DATA channel is used for data transmission. COL channel is used to avoid the BIP propagation problem. Thus, the collision among different packets does not occur as different channels are used for different types of packets. The working mechanism of the proposed scheme is as follows. In step 1, if a node S wishes to transmit it first listen to its neighbors, if there is a transmission in progress then it waits for some random time else go to step 2. In step 2, S broadcast a BIP packet and waits for the response. If the packets collision occurs then go to step 1 otherwise go to step 3. In step 3, when the receiver R receives the BIP or collision it will either broadcast the BIP with maximum power on COL channel if R wants to transmit or with half power if R wants to receive or remains silent if neither want to receive nor send. In step 4, if S encounter any collision on COL channel, go to step 1 after some wait, else start data transmission. If S receive BIP on BIP channel during data transmission, it sends BIP on COL channel.

Objectives [11]	(i) The data and control packets are transmitted on separate channels so data packets collision is avoided. (ii) Network throughput can be increased by controlling the transmission range for data packets delivery. (iii) Single control message BIP is used for collision avoidance. (iv) Power will be saved with a smaller transmission range for data transmission. (v) A minimum number of collisions will occur. (vi) A lifetime of the network will be decreased. (vi) Throughput would be increased with the simultaneous transmission on different channels.
Findings	(i) If a malicious node regularly broadcast BIP packets then throughput may be decreased. (ii) It affects the performance if real-time data is to be processed. (iii) It is assumed that nodes in the ad-hoc network would be stationary and this is not practical. (iv) It does not work if two-hop neighbors are used. (v) One hop concept is very practical with clustering, but clustering is ignored.

C. TEA-CBRP: Distributed cluster head election in MANET [22]

In this paper, three key decision parameter values are used to select the cluster heads in MANET. These parameters are; 1) remaining power (REL) of a node, 2) its trust value (TV) and 3) the time of availability (ToA).

The trust value can be used to completely remove the likelihood of malicious nodes from the cluster headset. The remaining power of nodes helps in removing selfish nodes from the cluster headset. The availability factor (ToA) of a node can't be ignored to form stable clusters in mobile ad hoc network. The first step in this algorithm is identifying the main parameters for cluster head selection and hierarchy development. The second step involves the calculation of weights. In the third step, the final weight values based on the values obtained from the second step are computed. The cluster heads are selected based on high weight values in the last step.

Objectives [22]	(i) In this paper, the most important parameters like remaining energy, trust value and the time of availability are used to select the most cooperative nodes as the cluster heads. (ii) The network performance can be improved by removing selfish and malicious nodes from being selected as a cluster head. (iii) An approach is suggested to select a cooperative node based on key parameters such as REL, ToA, and TV as the cluster head. (iv) To form stable clusters, an enhancement to the above technique with secondary cluster head is proposed. The secondary cluster heads will perform its operation just like the primary cluster head whenever the primary cluster head moves from the cluster range.
Findings	(i) In this study, the nodes with high energy and trust value are selected as cluster heads which may result in the unbalanced partition of the network. (ii) The nodes with low connectivity may be elected as a cluster head. (iii) The mobility of a node to become a cluster head is ignored in this study that may results poorly than existing protocols. (iv) Neighbor's behavior is not considered during the cluster formation process.

D. A Preference-Based Protocol for Trust and Head Selection for Cluster-Based MANET [27]

This paper proposes an organized solution for preventing the malicious node from the routing process. The work is inspired by the un-balanced consideration of external and internal factors of a node in the ad-hoc network. Thus, the lifetime of a mobile ad hoc network would increase. The nodes within the cluster observe the behavior of its neighbors and the trust value of its neighbors are updated. The paper considers numerous security parameters and presents a well-defined preference based

trust election (PTA) algorithm. Consequently, the packet misrouting attacks, packet dropping, packet injection, and alteration has been prevented. The cluster head nodes are selected based on external and internal factors of a node. The proposed scheme is well suited for high mobility networks. The algorithm is validated through simulation and the results are compared with existing protocols. The authors claim that the proposed solution lengthen the network lifetime and most suitable nodes are elected for cluster heads and forwarded to form stable clusters. This paper provides a base for trust-based clustering approaches and stable communication.

Objectives [27]	(i) The algorithm is based on two well-known techniques named preference based head algorithm (PHA) and preference based trust algorithm (PTA). The predefined trust assignment for a node is provided using (PTA), and clusters are efficiently formed with a cluster head selection algorithm using PHA. (ii) The preference-based trust algorithm is used to identify the malicious node. The weighting coefficients are calculated based on security parameters (packet dropping ratios, packet misrouting, and packet injection and packet alteration). (iii) The cluster heads are selected based on internal factors such as remaining power, remaining processing, memory and external factors such as mobility, connectivity, and distance of a node. (iv) An efficient routing mechanism ILCRP [145] is used for routing the packets from source to destination.
Findings	(i) The stability of node is calculated by low mobility, connectivity and power and a node with a good reputation and high stability but with different mobility, the direction may be elected as a cluster head and thus results as short span clusters. (ii) The protocol is compared with LEACH a sensor network based clustering protocol which shows poor validation because the nature of the ad hoc network is very different from the sensor network. (iii) The quality of neighbor (mobility speed and direction) is not considered and a neighbor may not remain the neighbor after cluster formation (may leave the cluster quickly).

E. Effective Path Discovery among Clusters for Secure Transmission [28]

The security threats affect the development of ad hoc network due to its vulnerable nature. To overcome such threats, a cluster based efficient anonymous protocol for mobile ad hoc network is proposed in this work. The

nodes first determine their neighbors and RSA algorithm is used for the neighbor detection process. Route request messages are broadcasted for route discovery through neighbor nodes after neighbor's discovery. The cluster is constructed to reduce the network messages overhead by preventing the nodes to broadcast the messages within the cluster. Each cluster in the network must have a representative node called cluster head. If a node wants to communicate, the route request message is sent to its cluster head instead of neighbor nodes. To find the shortest path from source to destination, the cluster head consults with other cluster heads instead of its members. Hence, all the nodes in the network did not participate in the shortest path discovery process and hence the control overhead is reduced. If multiple paths from source to the destination exists, the data is sent through the shortest route. Thus, the security threats would be prevented and the overall performance of the network is improved.

Objectives [28]	(i) Secure neighbors are identified using cryptographic techniques such as public key and shared secret key cryptography. (ii) The neighbors are clustered to form zones and the RREQ messages are transmitted to nodes via cluster heads thus reduce the network overhead. (iii) The cluster heads decide which nodes should participate in the routing and thus the security threats would be prevented. (iv) The overall traffic is also reduced and results in an increase in network lifetime. (v) The security and anonymity of the routing scheme with privacy preservation are ensured with the proposed method. (vi) the neighbor discovery scheme is used to identify all possible neighbors of a node in its transmission range and more resources are obtained from its neighbors.
Findings	(i) Highest energy nodes are best candidates to perform the role of cluster head and all the cluster heads may belong to one part of the network. (ii) The network may have unbalanced partition as the number of neighbors nodes a node must have during cluster head selection is not considered. (iii) The mobility of nodes before and after cluster formation is completely ignored.

F. Privacy preservation and protection for a cluster-based geographic routing protocol in MANET [32]

In this work, the cluster heads are elected based on node value. The value of a node is computed based on several matrices like remaining energy, connectivity, and

node mobility. The proposed algorithm assumes two different types of nodes in the cluster that are furnished with antenna and GPS enable nodes. The cluster head election is the responsibility of Gnode in a cluster. The clustering procedure is started by at least one GNode in a cluster and elect a node as cluster head with low mobility and high energy. Each cluster head initializes group signature in order to achieve anonymity and privacy protection of cluster members after the cluster heads election. The routing packets are secured with encryption before transmission to secure the data from annoying attempts. The proposed scheme works in three phases. In the first phase, the cluster is formed. In the second phase, the anonymity and privacy of cluster members are guaranteed. In the last phase, the data is transmitted to its destination securely using an encryption mechanism. To save the energy, the GPS enabled nodes goes to sleep state when idle. The antenna enables nodes to have the ability to receive signals from other cluster members. It can also measure the received signal strength and the arrival angle of the signal. The antenna enables nodes can compute its location with the aid of GPS enabled node.

Objectives [32]	(i) The routing packets are protected with encryption and the control overhead of topology maintenance is reduced with clustering. (ii) The cluster-based geographic routing is protected from different attacks by a secure authentication scheme. (iii) The cluster head initiates a group signature in order to achieve privacy and anonymity protection of cluster members. (iv) The re-configuration and re-clustering process are invoked when the nodes leave one cluster and are in the range of another cluster head. (v) A location update mechanism is executed in order to prevent the location error produced in the course of routing.
Findings	(i) The proposed algorithm assumes that a least one GPS enabled node must be present in a cluster which is not possible when all the nodes are moving in random directions. (ii) The relative mobility is not considered when a cluster head is selected so a node with different direction but same mobility speed may be elected as cluster head resulting in stable clusters. (iii) The protocol degrades its performance when all the nodes in the network are enabled with the antenna.

G. A Cluster-Based Reliable Token Circulation Scheme for Group Communication in MANET [34]

In this article, a cluster based routing scheme is proposed for total order message delivery to improve group communication. The scheme aims to group the neighbor nodes and provide scalability in the large-scale MANET. Two cluster heads called primary and secondary cluster heads are assumed in this paper. The aim of secondary cluster heads in a cluster is to help the primary cluster heads in case of overloads like routing information stored, token storage, complex computation and the failure of the primary cluster head. Along these lines, the trustworthiness of information in the cluster heads is attained. An improved version of the least recent LR token circulation mechanism is suggested to guarantee group communication among member nodes. The primary cluster head observes the token circulation within a cluster. With cluster-based networks, the token loss or node failure is easily identified. The token is then regenerated to make sure the group communication. When the primary cluster head fails due to some reason, the secondary cluster head monitors the token circulation inside the cluster.

Objectives [34]	(i) This paper suggests a new token circulation mechanism to offer a reliable and adaptable group communication by means of an adaptive secondary cluster head-aided clustering algorithm. The clustering algorithm is used to form variable length clusters and the token circulation approach handles node failures and token loss. (ii) For the assistance of primary cluster heads, a secondary cluster head is also maintained inside the cluster to share the load such as token monitoring, topology related information storage, clustering functionalities etc. (iii) The token circulation mechanism is simplified with dividing the network into different clusters where each cluster head play the role of a monitor and thus the network will function properly with the help of secondary cluster heads. (iv) The clustering algorithm is adaptive in nature and the cluster merging and splitting process are initiated when needed depending on the threshold. The threshold is different for different areas of the network and thus the algorithm is more flexible.
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Findings	(i). The secondary cluster head is used for computation and storage and it creates more overhead during secondary cluster head selection because computation is more economical than transmission. (ii) A node with a high degree is selected as a cluster head and low energy nodes may be selected for this purpose results frequent cluster head changes. (iii) The mobility of a node should be considered when selecting cluster heads but in this approach, it is not mentioned. (iv) The protocol is designed for group communication within the cluster and may not work properly in case of random moving direction.
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CONCLUSION AND FUTURE DIRECTIONS

The nodes cooperation and reliability is very important for the proper functioning of mobile ad hoc networks. In mobile ad hoc networks, some nodes reveal false information to save their resources during the cluster formation process. So the presence of selfish nodes may result in the unbalanced partition and the lifetime of the network may be reduced due to topology maintenance overhead. Other resources like node battery, bandwidth may not be properly utilized. The security of data packets during transmission from different attacks also need careful attention. The problems discussed above motivates us to discuss some recent algorithms that address the issues. In these algorithms, the reliability is achieved through different token circulation schemes in a clustered environment. The clustered structure is also very useful in finding selfish nodes. Some authors propose an incentive-based mechanism to prevent selfishness in the network. The network services are granted based on the reputation of nodes. The reputation is calculated based on the truthfulness of the nodes in the clustering formation process. To obtain more services from the network, the node needs to cooperate and reveal its true information. Some authors use encryption technique to secure the data during routing from source to destination.

The authors focus on the trust and reputation of the nodes in cluster-based mobile ad hoc network but the cluster formation process used in these schemes has some serious limitations. In paper [11], the cluster head

selection mechanism is not mentioned. The cluster-based environment will help when the balanced and stable clusters are formed combined with considering the trust and reputation matrices. In some papers like [8][22][28], the remaining energy and connectivity index are used to form clusters. In these algorithms, the mobility matrix is ignored and it results in an unstable cluster structure when the nodes are moving from one location to other location. Similarly, the communication workload of a cluster head is not considered during the clustering process.

The important parameter in simulating an algorithm is the mobility model and is not mentioned in papers [11] [28] [42]. The simulation matrices selected for comparison by some authors are not satisfactory like an end to end delay, packet delivery ratio etc. the authors of paper [29] compared their results with LEACH protocol that is a sensor network based clustering mechanism and seems very confusing because MANETs and WSNs are very different networks in nature. We recommend that the simulation matrices for clustering algorithms that are: cluster headcount, re-affiliation rate, throughput, cluster lifetime, energy consumption, control overhead and etc.

The stability of the clustering structure is very important to achieve long life clustering networks. To achieve stable clusters in mobile ad hoc networks, the parameters that need careful attention are mentioned. These matrices are nodes residual energy (RE), nodes connectivity index or degree (ND), Nodes relative mobility (RM) i.e. node speed and direction, the quality of neighbors (NQ), the node communication load (CL), trust and reputation of nodes (TR). The clustering algorithm should take into consideration the above-mentioned matrices while selecting cluster heads. Thus, the network lifetime would increase with high throughput.

REFERENCES

1. Ling Fu Xie et al, "Leader Based Group Routing in Disconnected Mobile Ad Hoc Networks with Group Mobility", *Wireless Pers Commun* (2013) 71:2003–2021 DOI 10.1007/s11277-012-0920-z.
2. Xibin, Zhao a, William N.N. Hung b, Yafei Yang d, Xiaoyu Song, "Optimizing communication in mobile ad hoc network clustering", *Computers in Industry* 64 (2013) 849–853.
3. Hui Cheng a, Shengxiang Yang b, Jiannong Cao, "Dynamic genetic algorithms for the dynamic load balanced clustering problem in mobile ad hoc networks", *Expert Systems with Applications* 40 (2013) 1381–1392.

4. Hamid Ali, Waseem Shahzad, Farrukh Aslam Khan, "Energy-efficient clustering in mobile ad-hoc networks using multi-objective particle swarm optimization", *Applied Soft Computing* 12 (2012) 1913–1928.
5. Charalampos Konstantopoulos a, Damianos Gavalas b, Grammati Pantziou, "Clustering in mobile ad hoc networks through neighborhood stability-based mobility prediction", *Computer Networks* 52 (2008) 1797–1824.
6. Javad Akbari Torkestani · Mohammad Reza Meybodi, "A mobility-based cluster formation algorithm for wireless mobile ad-hoc networks", *Cluster Comput* (2011) 14:311–324, DOI 10.1007/s10586-011-0161-z
7. Shadi S. Basurra a, Marina De Vos a, Julian Padget, Yusheng Ji, Tim Lewis c, Simon Armour, "Energy efficient zone based routing protocol for MANETs", *Ad Hoc Networks* 25 (2015) 16–37.
8. Jean-Marc Robert, Hadi Otrok b, Abdelkarim Chriqi, "RBC-OLSR: Reputation-based clustering OLSR protocol for wireless ad hoc networks", *Computer Communications* 35 (2012) 487–499.
9. Lyes Dekar, Hamamache Kheddouci, "A cluster-based mobility prediction scheme for ad hoc networks", *Ad Hoc Networks* 6 (2008) 168–194.
10. Mohammed Tarique, Kemal E. Tepe, "Minimum energy hierarchical dynamic source routing for Mobile Ad Hoc Networks", *Ad Hoc Networks* 7 (2009) 1125–1135.
11. Seungjin Park a, Seong-Moo Yoo, "An efficient reliable one-hop broadcast in mobile ad hoc networks", *Ad Hoc Networks* 11 (2013) 19–28.
12. João Trindade, Teresa Vazão, "Routing on large-scale mobile ad hoc networks using bloom filters", *Ad Hoc Networks* 23 (2014) 34–51.
13. Rawashdeh and Mahmud: A novel algorithm to form stable clusters in vehicular ad hoc networks on highways. *EURASIP Journal on Wireless Communications and Networking* 2012:15.
14. Hui Cheng, Shengxiang Yang, "Genetic Algorithms with Elitism-based Immigrants for Dynamic Load Balanced Clustering Problem in Mobile Ad Hoc Networks", 2011 IEEE.
15. Syed Zohaib Hussain Zahidi, Fadi Aloul, Member, IEEE, Assim Sagahyoon, and Wassim El-Haj, "Optimizing Complex Cluster Formation in MANETs Using SAT/ILP Techniques", *IEEE SENSORS JOURNAL*, VOL. 13, NO. 6, JUNE 2013.
16. Gurpreet Singh a, Neeraj Kumarb, Anil Kumar Verma, "ANTALG: An Innovative ACO based Routing Algorithm for MANETs", *Journal of Network and Computer Applications* 45 (2014) 151–167.
17. R. Pandi Selvam, V.PalanisamyR. Pandi Selvam and V.Palanisamy, "An Optimized Cluster-Based Approach for MultiSource Multicast Routing Protocol in Mobile Ad Hoc Networks with Differential Evolution", *Proceedings of the International Conference on Pattern Recognition, Informatics and Medical Engineering*, March 21-23, 2012.
18. Mengqing Cai, Lanlan Rui, Danmei Liu, Haoqiu Huang, Xuesong Qiu, "Group Mobility Based Clustering Algorithm for Mobile Ad Hoc Networks", *APNOMS* (2015) 340-343.
19. S.S. Basurra, M. De Vos, J. Padget, Y. Ji, T. Lewis, S. Armour, "Energy Efficient Zone based Routing Protocol for MANETs", *Ad Hoc Networks* (2014), doi: <http://dx.doi.org/10.1016/j.adhoc.2014.09.010>.
20. V. V. Neethu and A K Singh, "Mobility Aware Loose Clustering for Mobile Ad hoc Network", *Procedia Computer Science* 54 (2015) 57 – 64.
21. Guizani B, Ayeb, B, Koukam, A, "A Stable K-hop clustering algorithm for routing in mobile ad hoc networks", *International Wireless Communications and Mobile Computing Conference* (2015) 659 – 664.
22. U. Venkanna · R. Leela Velusamy, "TEA-CBRP: Distributed cluster head election in MANET by using AHP, Peer-to-Peer Networking, and Applications", January 2016, Volume 9, Issue 1, pp 159-170.
23. Daichi Amagata et al, "Efficient cluster-based top-k query routing with data replication in MANETs", *Soft Computing* (2015) 1-18.
24. S. Zeeshan Hussain and Naeem Ahmad, "Cluster-Based Controlling of Route Exploring Packets in Ad-Hoc Networks", M.K. Kundu et al. (eds.), *Advanced Computing, Networking and Informatics* 2 (2014) 103-112.
25. M Qayyum et al, "Cluster-Based Data Replication Technique Based on Mobility Prediction in Mobile Ad Hoc Networks", *Proceedings of the 49th Annual Convention of the Computer Society of India CSI Volume 2 Volume 338 of the series Advances in Intelligent Systems and Computing* pp 315-328.
26. D.S.M. Hassan et al., "RCA: Efficient connected dominated clustering algorithm for mobile ad hoc networks", *Comput. Netw.* (2014), <http://dx.doi.org/10.1016/j.comnet.2014.10.010>.
27. R Mysamy et al, "A Preference-Based Protocol for Trust and Head Selection for Cluster-Based MANET", *Wireless Personal Communications* (2015) pp 1-17.
28. L.P. Suresh et al. (eds.), "Effective Path Discovery Among Clusters for Secure Transmission of Data in MANET", *Artificial Intelligence and Evolutionary Algorithms in Engineering Systems, Advances in Intelligent Systems and Computing* (2015) 324 499-509, DOI 10.1007/978-81-322-2126-5_55.
29. Keerthipriya N et al, "Adaptive Cluster Formation in MANET Using Particle Swarm Optimization", *IEEE 3rd International Conference on Signal Processing, Communication and Networking (ICSCN)* 2015, 978-1-4673-6823-0.
30. Sujoy S et al, "Effect of Optimal Cluster Head Placement in MANET through Multi-Objective GA", *IEEE International Conference on Advances in Computer Engineering and Applications (ICACEA)*, (2015) 832-837.
31. Yeon-Seok Kim, "A cluster-based web service discovery in MANET environments", *Mobile Information Systems* 7 (2011) 299–315 299. DOI 10.3233/MIS-2011-0124
32. B. Muthusenthil et al, "Privacy preservation, and protection for a cluster-based geographic routing protocol in MANET", *Wireless Networks*, (2015) pp 1-9.
33. S. Pathak, "A novel weight based clustering algorithm for routing in MANET", *Wireless Networks*, 11 (2015) pp 1-10.
34. P. Subathra et al, "A Cluster-Based Reliable Token Circulation Scheme for Group Communication in MANET", *Arab J Sci Eng* (2012) 37:647–664 DOI 10.1007/s13369-012-0195-4.
35. Liu, C., & Wu, J. (2009). "Efficient adaptive routing in delay tolerant networks." In *Proceedings of ICC* (pp. 1–5).
36. Amis, A., Prakash, R., Vuong, T., & Huynh, D. (2000). "Max-Min D-Cluster Formation in Wireless Ad Hoc Networks." *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, (pp. 32-41).
37. Gayathri, V., Sabu, E., & Srikanthan, T. (2007). "Size Restricted Cluster Formation and Cluster Maintenance Technique for Mobile Ad Hoc Networks." *International Journal of Network Management*, Vol. 17, (pp. 171–194).
38. Yang, W., & Zhang, Z. (2007). "A Weight- Based Clustering Algorithm for Mobile Ad Hoc Network." *Proceedings of 3rd International Conference on Wireless and Mobile Communications (ICWMC'07)*, (pp. 3-8).

39. [39] Chlamtac, I., Conti, M., & Liu, J. (2003). Mobile Ad Hoc Networking: Imperatives and Challenges. Elsevier Ad Hoc Networks Journal, Vol. 1, (pp. 13-64).
40. Al-Karaki, J., Kamal, A., & Ul-Mustafa, R. (2004). On the Optimal Clustering In Mobile Adhoc Network., First IEEE Consumer Communications and Networking Conference (CCNC), (pp. 71-76.).
41. Younis, O., & Fahmy, S. (2004). HEED A Hybrid Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks. IEEE Transactions on Mobile Computing, Volume: 3 Issue: 4. The USA, (pp 366-371).
42. Dai, F., & Wu, J. (2005). On Constructing K-Connected K-Dominating Set in Wireless Networks. Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium (IPDPS'05). Denver, Colorado, (pp. 81a).
43. Garcia, F., Solano, J., & Stojmenovic, I. (2003). Connectivity-Based K-Hop Clustering in Wireless Networks. Telecommunication Systems 22, (pp. 205-220).
44. Liu, J., Sailhan, F., Sacchetti, D., & Issarny, V. (2005). Group Management for Mobile Ad Hoc Networks: Design, Implementation, and Experiment. Proceedings of the 6th international conference on Mobile Data Management, Ayia Napa, Cyprus, (pp. 192-199).
45. Chinara, S., & Rath, K. (2009). TACA: A Topology Adaptive Clustering Algorithm For Mobile Ad Hoc Network. The 2009 World Congress in Computer Science Computer Engineering and Applied Computing. Las Vegas, USA.
46. Mai, K., Shin, D., & Choo, H. (2009). Toward Stable Clustering In Mobile Ad Hoc Networks. Information Networking, 2009. ICOIN 2009. International Conference on, (pp. 308-310).
47. El-Bazzal, Z., Kadoch, M., Agba, L., Gagnon, F., & Bennani, M. (2006). An Efficient Management Algorithm for Clustering In Mobile Ad Hoc Network. International Workshop on Modeling Analysis and Simulation of Wireless and Mobile Systems. Torremolinos, Spain: ACM, (pp. 25-31).
48. Sucec, J., & Marsic, I. (2004). Hierarchical Routing Overhead in Mobile Ad Hoc Networks. IEEE Transactions on Mobile Computing, Volume: 3 Issue: 1, (pp. 46 – 56).
49. Tolba, F., Magoni, D., & Lorenz, P. (2007). Connectivity, energy & mobility driven Weighted clustering algorithm. in Proceedings of IEEE GLOBECOM 2007, (pp. 2786 – 2790).
50. V. Manquinho and J. Marques-Silva, "On using cutting planes in pseudo Boolean optimization," J. Satisfiab., Boolean Model. Comput., vol.2, pp. 209-219, Mar. 2006.
51. M. Ahmad, et al, Cluster-based Hierarchal Randomized Re-Routing for special events in Wireless Sensor Networks", Archives des Sciences, (2012), 65 (7), 69-79.
52. M. Ahmad et al, Energy-aware uniform cluster head distribution technique in wireless sensor networks, an international journal of computer science and network security, (2010) 10 (10) 97-102.

Appendix

Table 1. Trust and Reputation-Based Clustering Matrices

	Cluster head criteria		Neighb or method	Clustering parameters	Partition	No of clusters	Energy consideration	Clustering method	Reclusterin g
[8]	energy level, connectivity index	Proactive	Na	nodes with high energy and high connectivity index are elected	not fixed	Na	considered and CH selection is based on the energy level	Na	
[11]	NA	Proactive	hop count	NA	Channel s based transmiss ion	NA	NA	NA	
[22]	Trust value, remaining energy and time of availability	NA	transmi ssion range with 250 m	1-hop	random	Rando m	Yes	NA	
[27]	trust value, remaining energy, connectivity, and mobility	Proactive	one hop	If the trust value of the node is greater or equal to thresh hold then the node may be considered as a cluster member.	dynamic	Rando m	Yes	one-hop	yes
[28]	high energy nodes are best candidates for cluster head	Reactive	Multi-hop	the nodes with trust form a cluster	random	Na	Yes	multi-hop	not mentioned
[32]	mobility, energy and degree difference	Proactive	one hop	the node with the highest node value is chosen as a cluster head	mixed	NA	Yes	Multihop	yes
[34]	a node with the maximum neighbor is selected as a primary cluster head and the secondary cluster head is selected from the neighbors of the primary cluster head based on the degree	Proactive	one hop	the nodes join the nearest cluster head and in case of a tie the cluster with fewer members are selected	unbalan ced based on cluster head potential to handle the nodes	Rando m	No	any number of hops away from the primary cluster heads flexible size	yes at constant time interval the cluster head changes

Table 2. Trust and Reputation-Based Clustering Simulation					
	Mobility Model	Simulation tool	Performance matrices	Compared to	Simulation matrices
[8]	random walk	Matlab 8.1	Numbers of MPR nodes selected by the different protocols and their impact on the network lifetime. The impact of the selfish nodes on the network performances.	ZRP	The packets loss ratio, The control packets ratio, The route unavailability ratio,
[22]	Random mobility model	NS-2	Packet delivery ratio, an Average end to end latency, Routing packet overhead, Number of times CH changes	AODV[107], CBRP	Area 1000 m X 1000 m, 50-200 nodes, transmission range 250, node speed 30m/s with UDP traffic and 20 connections
[11]	NA	NA	The number of collisions, The number of successful transmissions, and The number of successful transmissions with different packet sizes.	AODV[107], OLSR[108], ZRP	FTP – Throughput, Distribution of end to end delay time 3000 nodes, Total control packets sent by the routing protocol.
[27]	random waypoint	NS-2	Packet Delivery Ratio, Control Overhead, Throughput, Jitter, Packet Dropping	2ACK[148], CBTRP[147], LEACH[146]	two ray ground propagation model, the transmission range is 250 m, the bit rate of 11 Mbps, packet size is 512 bytes and simulation time 800 s.
[28]	Na	ns2	Packet loss, packet delivery ratio, and network overhead.	Na	NA
[32]	NA	NS-2	Average end-to-end delay, Average Packet Delivery Ratio, Energy Consumption, Computational Overhead	ALARM [164], ESGR [165]	Simulation time 50 s, Packet size 512 bytes, Receiving power 0.375 W, Transmit power 0.375 W, nodes 20–100, Number of attackers 10,15,20,25 and 30, Area 500* 500 m.
[34]	Random Way Point	NS-2	Average Number of Clusters, Average Number of Cluster head Changes Average Number of Secondary cluster head Changes, Average Number of Primary Cluster head Changes, Average Round Length, Message Overhead.	MOBIC[101], Lowest ID	Node placement Random, uniform Terrain range 1,000 × 1,000 m ² , Transmission range 25–250m, Channel bandwidth 2 Mbps Speed 10–20 m/s, Simulation time 1,000 s, Data Packet size 512 bytes Packet rate 2 packets/s, Number of mobile nodes 25–100.