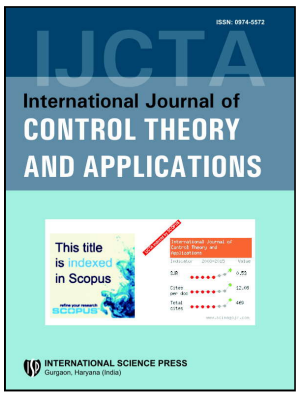


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# A Survey on Efficiency of Clustering Schemes for Routing Protocols in MANET

**Naghma Khatoon[1] and Amritanjali[2]**

[1] *Department of Computer Science and Engineering BIT Mesra, Ranchi, India, Email: naghma.bit@gmail.com*
[2] *Department of Computer Science and Engineering BIT Mesra, Ranchi, India, Email: amritanjali@bitmesra.ac.in*

***Abstract:*** Mobile ad-hoc networks (MANETs) are wireless network without any fixed infrastructure, consisting of autonomous mobile devices that are interconnected via wireless media. In recent years MANET become one of the most prevalent area of research because of its inevitable characteristics. However, resource limitations, energy efficiency, scalability and security are the major challenging concerns in such networks. Various protocols with different routing methodology and the information used to make routing decisions have been developed for MANET. Recently many efficient clustering schemes have been proposed to provide useful features like network scalability, fault tolerance and reduction of communication overheads. This paper presents a survey on the basic routing protocols and the use of clustering approaches to increase their efficiency along with providing security for clusters.

***Keywords:*** MANET, clustering, congestion status, secured clustering

## 1. INTRODUCTION

MANETs are infrastructure less networks that are formed arbitrarily by a set of mobile devices that come within the transmission range of each other (Figure 1). Here, routing is a way to find out an efficient path from source node to a destination node without the aid of any established infrastructure like base station or access point used in a cellular network. Some considerations should be taken while designing protocols for MANET like, it should be simple, reliable and efficient, distributed, quick adaptation to topology changes and traffic pattern, protocol reaction to topology changes should produce minimal control overhead, bandwidth and energy efficient, mobility management and scalability. Routing in MANET can be using flat structure or hierarchical structure. In routing protocols with flat structure, each node has the same responsibility of disseminating control packets across the network. This approach suits well for small network but doesn't allow the scalability when the number of nodes in the network increases. In large network, flat routing approach produces an excessive control overheads resulting in the saturation of the network. The second approach is the hierarchical approach of routing which divide the network into smaller virtual subgroups called clusters. This approach handles the scalability in MANET along with easy handling of unpredictable topology changes in an efficient manner. Here not all the nodes but only selected nodes have the responsibility of routing packets, which also save the energy consumption of mobile nodes which ultimately increases their lifetime.

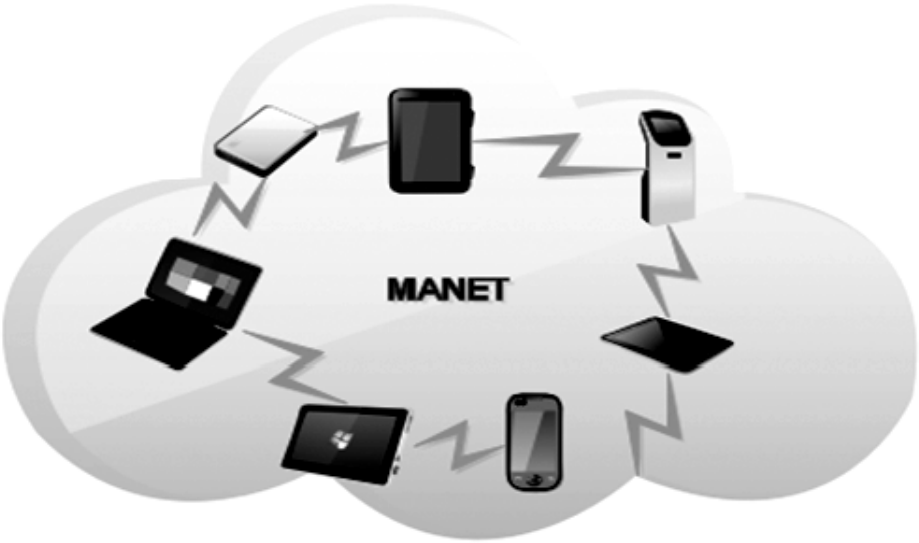


**Figure 1: Mobile ad-hoc network**

The rest of the paper is organized as follows: we start by introducing basic routing protocols in MANET in section II. Then we present different clustering approaches in section III. Section IV presents a brief survey of related works on increasing efficiency of AODV with clustering. In section V we have reviewed some trust based clustering approaches that are applied on the basic routing protocols in order to improve network resource utilization and provide stability to the clusters. Finally in section VI we conclude the paper.

## 2. BASIC ROUTING PROTOCOLS IN MANET

We have reviewed several MANET routing protocols. The basic routing protocols in MANET are categorized by the features they exhibit. Ad-hoc routing protocols are classified into three categories i.e. proactive, reactive and hybrid. The proactive routing protocols try to maintain consistent and up-to-date routing information from each source node to every destination node in the network. Here, each node maintains routing table to store routing information. In order to maintain consistency of the network, nodes periodically update their routing table by disseminating update packets throughout the network. The routing protocols under this category vary in the area of number of compulsory routing tables and the methods of broadcasting update in the network structure. DSDV (Destination Sequenced Distance Vector) [1], WRP (Wireless Routing Protocol) [21] are some examples of proactive routing protocols. Reactive routing protocols are on-demand where routes are created only when needed by the source node. When a node needs to send data to a desired destination, it starts broadcasting a RREQ (Route Request) packet throughout the network. This process stops when a route to the desired destination is found out or all different possible routes are examined. Once a route has been established, it is maintained by a route maintenance process until the destination becomes inaccessible i.e. route failure or route is no longer needed, e.g. DSR (Dynamic Source Routing) [16] and AODV (Ad-hoc On-demand Distance Vector) [3].

Hybrid routing protocols combine the best features of both proactive and reactive protocols. Examples of such routing protocols are ZRP (Zone Routing Protocol) [2] and ZHLS (Zone-based Hierarchical Link State) routing protocol [20].

None of the protocols examined so far is perfect for every situation. Proactive protocols are good for small network with less mobile nodes. As mobility and the network size increases it leads to high overhead because of periodic updates of routing tables. In reactive routing protocols there are less overhead because of no need of disseminating periodic updates but there is route discovery delay as compared to proactive protocols. This is

because here routes are not pre-established and the process of path searching from source to destination is started whenever needed which is time consuming.

Hybrid protocols were proposed to reduce the control overhead of proactive routing protocols and also lessen the latency caused due to route discovery in reactive routing protocols. Here routes within a zone are kept up-to-date in a proactive manner and routes for different zones are set-up in a reactive manner. These protocols work better as compared to reactive and proactive protocols. However, the problem is with zone creation and zone maintenance in high mobility scenario which reduces its effectiveness.

There are various research works done by many researchers in last few years in the field of MANET to improve the efficiency of one of the most important routing protocol i.e. AODV [5][11][12][19]. Till now it was assumed that the nodes in MANET behave according to the protocol rules and lack security mechanism [19]. As a result of which many attacks may come from any direction attacking any node of MANET. Because of unique nature of such type of network the concept of wired network security can't be implemented with MANET. Zapata and Asokan in 2002 induced the concept of security to AODV routing protocol and proposed Secured AODV (SAODV) [12]. SAODV uses public key cryptography extending the AODV message format to include parameters for securing routing messages. Although SAODV provides security however, its routing messages are significantly larger and require heavy computation time. Thus, Adaptive-SAODV (A-SAODV) was proposed which optimizes the performance of routing operation using load balancing [5].

Flat structured routing protocols works well as long as the size of the network is small. As the network size increases, route establishment between a source-destination pair leads to blindly broadcasting of RREQ packets which leads to very high routing overhead i.e. a congestive scenario is developed due to these routing mechanisms [11]. For better performance of MANET, a good approach is to use hierarchical routing structure which aggregate existing routing protocols with clustering schemes for minimizing control overheads and improving throughput, spatial reuse, scalability and power consumption.

## 3. CLUSTER BASED ROUTING IN MANET

Clustering in MANET is an important approach in order to achieve scalability in the presence of large network with large number of mobile nodes. Clustering, in fact is not a routing protocol instead it is a mechanism which provides a way of grouping mobile nodes into logical sub-groups called clusters which make network management quite easier. Nodes in a cluster have different responsibilities based on their status as Cluster Head (CH), gateway and cluster member (Figure 2). A CH acts as a local coordinator for its cluster and perform intra-cluster transmission. A cluster gateway lies in the transmission range of two or more CHs and perform inter-cluster transmission [18]. Cluster members are ordinary nodes of a cluster. Each CH maintainstwo tables: routing table (store routing information) and connectivity table (keep records of its cluster members and neighboring CHs). These tables are updated by periodic "HELLO" packets. Thus, by using clustering approach each member node does not require to maintain the information of the whole network, rather they only require to store the informationabout nodes in the vicinity as well as the information regarding the CH. It helps to reduce the bandwidth consumption over the network because here the control packets are not blindly flooded, instead only from CH to CH via gateway nodes.

### 3.1. Cluster Head selection techniques

A CH should be one of the most eligible and responsible node of a cluster as it has to perform extra responsibilities and will consume more battery power. A CH selection technique should be such that it will select the most suitable node as a CH.

Several clustering algorithms have been proposed by many researchers in literature. We have reviewed a number of proposed clustering schemes for MANET [13][14][22][23][24]. Different metrics are used for the selection of CHs as shown in Figure 3.

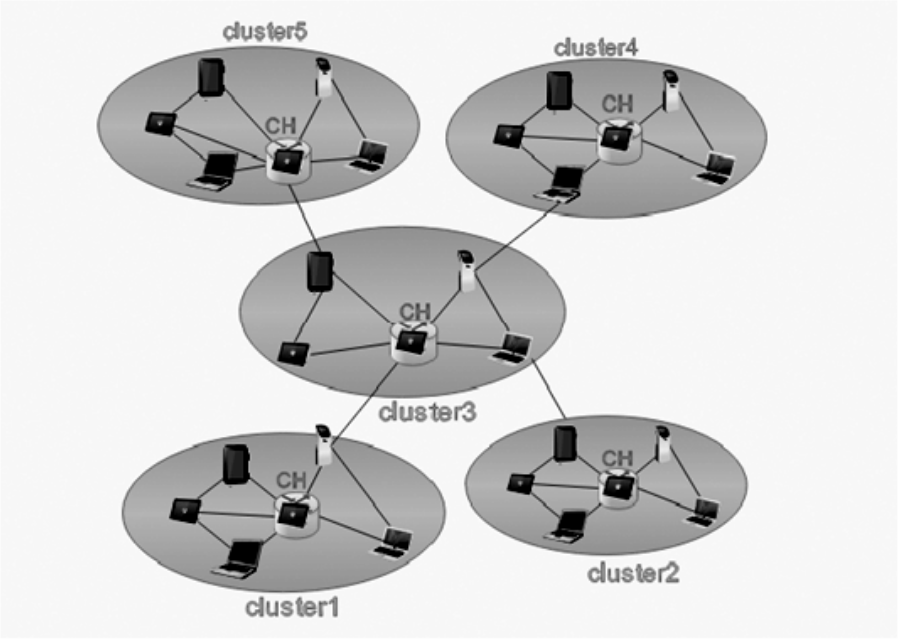


**Figure 2: Illustration of clusters in MANET**

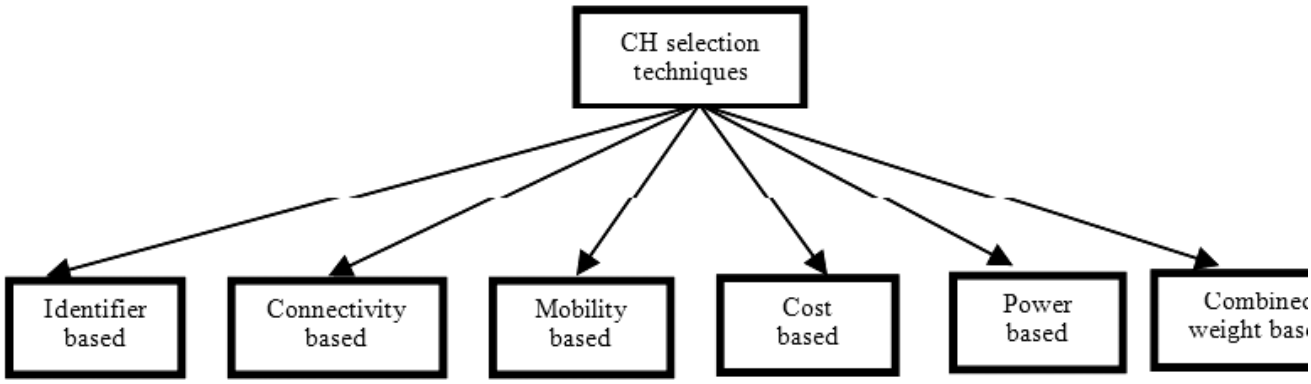


**Figure 3: CH selection techniques**

In identifier based clustering algorithms, election of CHs is based on the identity of a node without any other eligibility qualifications to become a CH. Each node in the network is assigned with a unique identity which is an arbitrary number assigned to a node when it first enters the network. On receiving HELLO messages from its neighbors, a node compare it's ID with its neighbor's IDs. When it finds that its ID is minimum among all its neighbors, it will declare itself as a CH. Here election of CH is solely based on node's IDs without considering any other qualifications of a node, it is most probable that smaller ID nodes will always become a CH. Although this approach is simple with less overhead, but since node's ID is fixed and is not going to change with time, smaller ID nodes will always become CH than other more eligible nodes. The main drawback of LIC is the energy depletion of lowest ID nodesmore frequently than other nodes.

Parekh proposed Highest Connectivity Clustering (HCC). This algorithm is based on node's degree of connectivity, which depends on its distance from other nodes [14]. Each node broadcast its ID to the neighboring nodes which are within its transmission range through HELLO packets. In this way each node get the knowledge of its degree of connectivity. A node having maximum degree of connectivity is chosen as a CH and all its direct neighbors become members of that cluster. Once these nodes get assigned with a CH, they will no longer take

part in election process further. The rate of change in CH is low but as the mobility increases the number of re-affiliation increases. Also here, there is no bound on upper and lower limitations on the size of clusters. These drawbacks causes low throughput with this approach.

Er and Seah [27] proposed mobility based clustering algorithm which divides a network into d-hop clusters. Here cluster diameters are flexible and is adaptable with respect to node's mobility. A node can estimate its distance from its neighboringnodes by measuring the strength of the received signal. Stronger received signal means the two nodes are closer to each other. Instead of calculating the physical distance between two nodes, the variation of estimated distances between them is calculated. This algorithm requires calculating five terms: the estimated distance between nodes, the relative mobility between nodes, the variation of estimated distance over time, the local stability and the estimated mean distance. Relative mobility is the difference of the estimated distance of one node with respect to another at two successive time period. The variation of estimated distance and the relative mobility between nodes is used to calculate the local stability which is used for selection of CH. A CH is the node with lowest value of local stability among its neighbors.

Least Cluster head Change Algorithm (LCC) [28] is a cost based clustering approach which improves the algorithms of LIC and HCC. The cost effectiveness is due to the inclusion of the role of cluster maintenance after the initial cluster setup phase. LIC and HCC were periodic in nature i.e. clustering procedure is invoked periodically and nodes are re-elected from time to time so as to maintain some predefined characteristics for CHs. In LCC the clustering algorithm is divided into two parts i.e. cluster creation and cluster maintenance. Cluster creation is the initial phase which uses LIC for electing the lowest ID node as CH. After cluster formation re-clustering is not periodic but is event-driven that is invoked in two cases; first is when two CHs comes in range of each other, one has to give up its role of CH and the second is when a mobile node becomes isolated i.e. not comes in the transmission range of any CH. Thus LCC maintains cluster stability but re-clustering is still a bigger challenge as this algorithm too is not electing the most eligible node to be a CH which maintain the cluster for longer period of time.

Signal and Energy Efficient Clustering (SEEC) algorithm is one of power based clustering algorithm which is based on the signal strength and energy level of nodes [22]. The basic idea of this algorithm is to prevent the death of a CH and to make cluster stable for longer period of time. When the energy level of the CH falls below certain threshold, it resigns from CH and another node in the cluster act as a new CH. The algorithm minimizes the ripple effect of re-clustering by keeping the CH alive by switching the role of CH from one node to another node inside a cluster.

In [13], a combined weight based clustering algorithm (WCA) is proposed. A set of parameters are used for selection of CHs. These are the number of neighbors, distance with all neighbors, mobility, transmission power and battery power. In order to reduce communication overhead this procedure is not called periodically. It is invoked based on node's mobility and when current dominating set cannot cover all mobile nodes in the network. In this algorithm a pre-defined threshold is used showing the number of nodes a CH can handle efficiently. This solves the problem of overloading of CH and create homogeneous clusters having ideal number of nodes. The weight associated with a node $v_i$ is calculated as

$$w(v_i) = w_1\Delta(v_i) + w_2D(v_i) + w_3M(v_i) + w_4P(v_i)$$

Here, $M(v_i)$ is the measure of mobility, calculated by taking the average speed of every node during a specified time T. $\Delta(v_i)$ is the degree difference for each node, calculated as $\Delta(v_i) = |dv - \delta|$, here dv is the degree of node $v_i$ and $\delta$ is the pre-defined threshold value which shows maximum number of nodes a CH can handle. $D(v_i)$ is the sum of distances from a given node to all its neighbors.$P(v_i)$ is a measure of battery power consumed.A node is selected as CH which has the minimum calculated weight. WCA is a good approach as it reduces communication overhead. The most important factor of this algorithm is adding more than one parameter for the selection of eligible CHs, however it doesn't ensure the stability of CHs.

## 4. EFFICIENCY OF AODV WITH CLUSTERING

Here the main motivation is how to select a CH inside a cluster (the mechanism of cluster creation and cluster maintenance) in order to create stable clusters with less routing overhead so as to be aggregated with basic MANET routing protocols to increase its efficiency [9, 10].

Kaushik and Goyal in [6] proposed a clustering based AODV approach for MANET. This paper used on-demand routing protocol information for clustering. On-demand nature of clustering is based on AODV concept. It means no clusters are maintained until and unless they are needed. In order to reduce the congestion in relatively large network with high degree of nodes due to sending of many control packets in pure AODV, cluster-AODV is proposed to reduce routing overhead and provide good network resource utilization. Here a comparison was made between a pure AODV protocol and clustered AODV protocol. From that it can be concluded that the variation in loss of packet for AODV is more than clustered AODV. Thus, clustering architecture improves the scalability of the network and also reduces the communication overhead.

Amin, Wan and Budiarto proposed Energy Efficient Cluster Based Routing Protocol for MANETs [4]. Cluster based routing protocol (CBRP) which is one of the powerful and scalable routing protocol for ad hoc network have been modified for energy consideration and is used with the basic MANET routing protocol AODV, thus generating less overhead and increasing throughput. Out of many resources, energy of nodes is one of the critical factors in the operation of MANET. The performance of such a network can eventually be increased by increasing the lifetime of nodes, which in turn can be achieved by decreasing the energy consumption. Sleep mode is introduced for all idle nodes in the network except the CH and gateway nodes. This strategy helps to maximize the lifetime of nodes, stability, connectivity and saving battery in ad hoc networks. The work in this paper make it feasible to conserve energy of nodes, however calculating energy consumption for sending and receiving packets each time leads to overhead and takes time.

Phate, Saxena and Rizvi [17] proposed an enhancement to the AODV routing protocol. It uses the concept of a cluster based mechanism in order to support congestion control in MANET which provides a QoS aware path. Here also the scheme used is clustering. The selection of CH is on the basis of the congestion status of the nodes. The congestion status is calculated using formula:

$$\text{Status} = (1 - (\Sigma q_i / \Sigma b_i))$$

Here, 'q' is the number of packets there in a queue and 'b' is the buffer size of a node. Each node is inversely proportional to the status of nodes, i.e. a node with high calculated status is less congested and is thus selected as CH of a cluster.

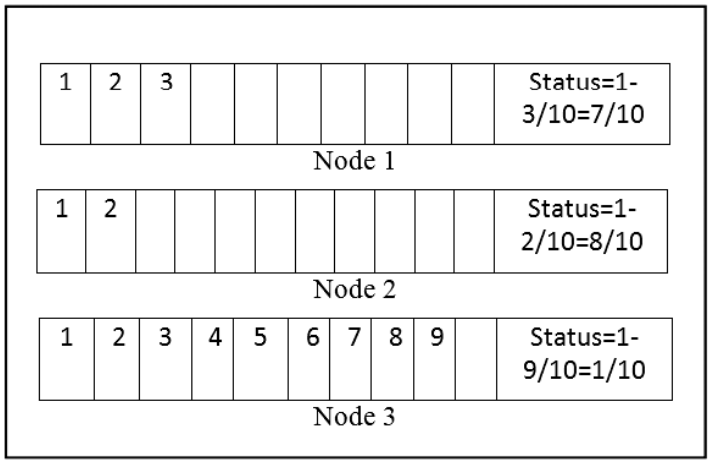


**Figure 4: Relationship between status and congestion**

From figure 4 we can see that node 2 with high calculated status is less congested and node 3 with less calculated status is more congested. Out of these three nodes, node 2 will be selected as CH. In the situation of a tie i.e. when two or more nodes have same calculated status, the node with minimum ID among them is selected as CH. The CH needs to be changed in case the congestion status and energy of the CH become less than some pre-defined threshold value. In that case the election process of CH will take place again. In this way the CH will never die and there is less likelihood of the failure of a root. In order to provide QoS based routing this approach uses AODV routing protocol. If a node wants to transmit data, it first sends a RREQ to its CH. The CH checks its routing table, and if it finds an unexpired path to the destination, communication will be started. If no path is found, it broadcast RREQ to its neighboring CHs. The process continues till it reaches the destination CH or an intermediate CH having a path to the desired destination. A RREP is send to the source CH and a path is established for communication. This approach improves the efficiency of AODV routing protocol by decreasing the number of overheads. However, in this approach CH is elected based only on congestion of each node.

In [23], a new enhanced version of weighted clustering algorithm have been proposed called Enhancement on Weighted Clustering Algorithm (EWCA). The parameters used for the selection of CHs are transmission power, transmission range, mobility, and battery energy. Here, the average number of cluster formation is reduced by avoiding the dynamic change of CH. EWCA take care of load balancing and improve stability of clusters in MANET.

In [24], the authors contributed in the enhancement of WCA and other similar algorithms and proposed a Node Quality based Clustered Algorithm (NQCA). Two models are used in this clustering algorithm i.e. node priority and range zone aggregation models. Based on the degree of a node selection priorities are assigned to them as priority of strong node is more than the priority of weak node, which in turn is more than the priority of border node. Similarly, in range zone aggregation model the transmission range of a node is virtually divided as excellent zone, intermediate zone and risked zone and accordingly priorities are assigned to the favorable and unfavorable nodes. The main idea behind dividing the transmission range zones into favorable and unfavorable is to elect only that node as CH which retains its connectivity with other nodes for longer duration of time. The selection of CH is based on the combined weight of remaining battery energy, stability factor, degree and mobility distance of a node. NQCA provides Quality of Clustering (QoC) by taking care of stability and load balancing clustering parameters. The proposed clustering approach ensures the stability of clusters, however the trustworthiness of CHs was still not assured.

## 5. SECURED CLUSTERING ALGORITHMS

In MANET, traditionally all clustering approaches work assuming that the network is in fully trusted environment where nodes are assumed to be cooperative in nature, which is actually not the case. Because of limited resources like battery power and bandwidth a node may become selfish and doesn't cooperate in the network and starts dropping the packets of other nodes in order to save its energy and bandwidth. In recent years, trust factors are included in several clustering approaches in MANET for providing secured clustering. The node's trustworthiness is evaluated based on some common trust parameters such as the type of data forwarded, data delivery rate, packet dropping ratio, packet misrouting ratio, packet falsely injected ratio and packet altering ratio.

Paramasivan and Kaliappan [25] in their work proposed a secure and fair cluster head selection protocol for enhancing security in mobile ad-hoc networks. It combines the weight based clustering algorithm (WCA) with the security components so as to elect a trusted node to be a CH. Based on security component a node is classified as normal, suspect or attacker and depending on this, different values are assigned to each of them. This is a good approach in trust based clustering in MANET, however, the basis of classification of nodes and the valued assigned to them is not fully mentioned.

Safa et al. [29] proposed a novel cluster based trust-aware routing protocol for MANET (CBTRP). Here each node in the network monitors the behavior of its neighboring nodes and forward packets only through the

trusted path. It was a good step to eliminate the intermediary malicious nodes from the routing path. However, in this algorithm all nodes are involved in nodes' monitoring resulting in battery consumption which ultimately lessen the network lifetime.

The above reviewed algorithms at a time select only one node as a CH for coordinating the cluster. Bani and Hijazi in their paper proposed Vice Cluster Head Cluster Based Routing Protocol (VCH- CBRP) that elect one Vice Cluster Head (VCH) in each cluster instead of electing only one CH in order to increase the lifetime of the cluster in case of sudden absence of the CH [7]. This approach automatically reduce the time required for re-selection of new CH in case of failure of first CH. It works well in an environment of low to medium mobility of nodes. However, in case of high mobility scenario, selection of vice cluster head unnecessarily increases communicationoverhead. Thus it is illogical to select second CH acting as a vice cluster head in high mobility environment. In table 1 we summarizes all the clustering schemes that we have discussed in this paper based on different clustering parameters.

**Table 1**
**Comparison table of clustering algorithms based on different parameters**

| *Clustering scheme* | *CH election* | *Cluster radius* | *Overlapping clusters* | *Clusters number* | *CH change* | *Cluster stability* | *Total overhead* |
|---|---|---|---|---|---|---|---|
| LIC | Lowest ID | One hop | Possible | High | Very high | Very low | high |
| HCC | Highest degree | One hop | No | High | Very high | Very low | High |
| LCC | Lowest ID | One hop | Possible | High | High | Low | High |
| Max-min D-cluster | Node ID | k-hop | No | High | Moderate | Low | Very high |
| Mob-D-Hop | Lowest mobility | k-hop | No | Low | Low | Very high | low |
| SEEC | Highest energy | One-hop | Yes | Moderate | Low | Relatively high | Relatively low |
| WCA | Combined weight | One-hop | Possible | Low | Low | High | High |
| NQCA | Combined weight | One-hop | Possible | Moderate | Low | Very high | Relatively low |
| CBTRP | Trust factor | One-hop | Possible | Moderate | Low | High | High |

## 6. CONCLUSION

As MANETs have achieved a great attention in the field of wireless communications because of its inevitable characteristics, a lot of research works have been undertaken addressing different issues related with them. One such issue is to provide scalability to the network. The problem of scalability have been resolved to a large extent by dividing a network with large number of mobile nodes into smaller groups called clusters. A number of clustering approaches have been proposed by many researchers. In this survey paper, we first provide fundamental concepts of different basic routing protocols used in MANETs including proactive, reactive and hybrid routing protocols. We then presented clustering overview and classified proposed clustering algorithms into six categories based on the cluster head selection criteria as identifier based, connectivity based, mobility based, cost based, power based and combined weight based. We also focused on the trust based clustering approaches that assured trustworthiness of elected cluster heads.In this article we emphasized on the survey of how clustering approaches provide efficiency to routing protocols in MANET. Through the detailed studies of various papers, we conclude that no clustering scheme is best suitable in all situations for providing efficiency to routing protocols in MANETs. However, the combined weight based clustering approaches elect a more suitable

cluster head by considering more than one clustering parameters. We summarized some important proposed clustering schemes based on their strength and limitations.

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