# A survey on connected dominating set construction algorithm for Mobile Adhoc Networks

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**Abstract**

The wireless type of ad hoc networks are usually viewed as an infra-structure less network, meaning a backbone less network, which does not rely on any fixed structures, these are multi-hop type of networks. This network usually comprises of mobile or wireless devices, these devices do not remain fixed at any particular points, namely the Mobile Ad Hoc Networks (MANETs), the Mobile Opportunistic Networks (MON), the Wireless Sensor Networks (WSNs) and the Under Water type of Acoustic Sensor Networks (UWASN).

These networks are found to withhold some significant type of characters, such as the requirement of minimum bandwidth and a dynamic type of topology. In these networks, energy is a precious resource, it is considered so as each of the individual nodes possess their own energy source based on their needs. For the purpose of increasing the lifetime of these mobile ad hoc networks it has turned out to be mandatory for incorporating routing algorithms that has proved it efficiency appropriately.

As far as a Connected Dominating Set (CDS) or a Virtual Backbone (VB) is considered, it is clearly observed as a subset of nodes. These nodes are capable of establishing the data communication oriented tasks, further they are found to involve themselves in the process of serving the nodes that are found outside the concerned backbone zone. One significant feature is that the CDS can be preferably opted as a communication layer; an additional feature is that only the nodes within the CDS have been found to possess the required permissions for transmitting the concerned data. The above mentioned features have enabled the network in suitably minimizing the transmission of redundant information, this quality greatly involves in the process of simplifying the corresponding structure of the concerned mobile network thus preserving the energy required in the process of information aggregation and filtering, routing and forwarding information required. This paper targets the various CDS construction algorithms that have been appropriately adopted in the literature.

A simple comparative study related to the major works involved in the CDS construction has been suitably offered, this stresses the importance on the type of algorithm to be employed, the type of technique to be incorporated, the performance metrics that can be adopted for achieving the required results.

***Keywords:*** Mobile Ad hoc network (MANET), Connected Dominating Set (CDS), Virtual backbone

## 1. INTRODUCTION

Mobile Ad-hoc networks (MANETs) are observed as a type of self-organizing and self configuring form of multi-hop wireless networks, it has been clearly observed that the structure of these networks tend to modify dynamically (Macker et al. [29]). It consists of wireless devices that communicate among themselves by means of adopting the wireless mode of communications.

The main objective of the Mobile ad hoc network is to initiate the communication process among the available senders and receivers in a network, these networks may at times comprise of nodes that are mobile or nodes that are fixed within the direct wireless transmission range of each other. This type of networks does not rely on a fixed infrastructure and any particular node can pose to be a traffic source, destination or forwarder. MANET is very flexible and resilient to node failures due to distributed nature.

Hence, it has been clearly observed that these mobile ad hoc networks are preferable in applications requiring rapid deployment and dynamic reconfiguration abilities. Some of the potential applications for MANETs are [21]: - Military application: MANETs satisfy the needs of military applications like battlefield survivability. Here, the MANET is deployed with wireless electronic devices carried in soldiers, tanks, airplane and other military equipment, to support communication among them in order to collaboratively achieve military goals, as there is an absence of any pre-defined infrastructure and connectivity in battlefield environments.

Emergency services: The occurring of natural disasters cannot be prevented at any cost, these disasters encountering every year have been found to ruin the lives of millions of people worldwide. The network services have thus become an essential source of service in the area of emergency services; hence it has turned out to be mandatory for regulating the services even in the absence of the required network components that have been purposefully disintegrated from the network due to the various forms of approaching disasters.
The field agents can suitably initiate the process of disaster recovery by means of communicating their research materials, for instance they can inform the other field agents about the approaching disaster or can inform them about the surviving network components or can even post an appropriate command.

### 1.1 Routing in MANETs

Routing is a fundamental issue for any network, the various involved routing protocols are thus observed as the source materials responsible for identifying and regulating the maintenance procedures of the concerned routes.

One of the most tedious tasks is to identify and maintain routing path in MANET with sudden topology changes due to nodes mobility. Various routing protocols have been introduced for MANETs, they are classified into proactive, reactive and hybrid according to routing strategy. A survey of the various established routing protocols in the concerned ad hoc networks have been proposed by Boukerche et al. [8].

The purpose of the Proactive routing protocols [12, 18] is to perfectly retain the existing rout information's in the network; such information's would be protected from all kinds of approaching offenses. These protocols usually take the form of tables that are meant for preserving the messages appropriately and are further found to involve themselves in the process of upgrading the tables at periodic intervals. Up gradation task would take care of of both regulating and maintaining the obtained fresh route information throughout the entire network. Another form of observed variation from that of the proactive routing algorithm is the reactive routing protocol, or the on-demand protocols [22, 32].

Apart from the task of possessing local links, these adopted protocols have been found to introduce a unique flooding route discovery mechanism. This particular strategy can be incorporated in the situations involved in the transmission of data to a particular destination. The observed limitation here is that they are not capable of retaining the routing information‘s in a periodic manner. They usually have two mechanisms, path identification and path maintenance, to create and maintain a route efficiently to prevent highly overloading the whole network.

In contrast to that of the proactive routing protocols these protocols possess the ability of preserving the concerned resources (e.g., node's battery and network bandwidth) yet they are found to be incapable of transmitting the data contents on an immediate basis. The final type of routing protocol is the so called hybrid routing protocol that essential adopts and utilizes the benefits of both the proactive and the reactive routing. The ultimate objective of designing these protocols is to enhance the scalability feature by means of permitting the nodes possessing close proximities to work together.

Their formation usually depends on the features of a specific backbone structure in order to minimize the path identification overheads and the encountering single point failures. It has been clearly observed that the Hybrid types of routing protocols are found to portray an enhanced performance level when compared with that of the proactive and the reactive routing strategies. The limitation observed here is an increased need of memory space, further the path to destination may be observed to be suboptimal in nature.

The basic concept of flooding based routing [46] is to transmit numerous packets into the network thus making it appear over loaded, the task of a node is to copy the prescribed contents into the other available nodes that are in connection to the concerned nodes, this task is thus established under the condition that the recipient node does not possess a copy the same. Several methods have been introduced for the purpose of establishing various control mechanisms for suitably alleviating the flooding problem. The ultimate objectives of the various routing strategies were to arrive at solutions for overcoming the problems related to the flooding strategy [10, 38 and 43]. One significant aspect of prime consideration is that even during the incorporation of the flooding process necessary measures would be taken for preserving the resources from damage during the flooding process.

Various strategies have been thus adopted for the purpose of emptying the buffer once the concerned messages have been delivered appropriately. History or prediction based routing, utilizes the past actions of the concerned encounters existing among the nodes, to make a more informed routing decision. Intuitively, any node that comes in contact with the destination many number of times is likely to encounter the destination again.

The above mentioned concepts have been considered as the basic principle behind the corresponding history based routing protocols [7, 24, 27, 35]. Sociality-aware routing [11, 15, 28, 38], works with reference to two significant approaches thus derived from the society: the first approach exhibits the fact that the people possessing intimate relationship with each other would generally reside in closed communities and the second approach stresses the fact that the people residing inside a particular community may possess various levels of popularity.

The above mentioned approaches have been observed to clearly establish the fact that the increasingly “popular” or “central” nodes are more likely to be opted as suitable carriers for the purpose of transmitting the concerned messages between disconnected communities, this process is observed to proceed till a particular node of the same community with a particular destination is reached.

## 2. CONNECTED DOMINATING SET (CDS)

A simple graph G = (V,E) can be used to represent a MANET or WSN, where V represents a set of mobile or sensor nodes and E represents a set of communication links between the nodes.

An edge (u,v) pair has been observed to insist that at a particular time, both nodes u and v would lie within their transmission range, therefore the appending work among the nodes is done with reference to the existing geographic distances among them. The topology of this type of graphs varies with respect to time as a result of the node mobility. 1.2.1 Definitions. This section provides some preliminary definitions that are relevant to the understanding of the rest of the chapters.

Definition 1.1. Graph: It is thus viewed as an ordered pair G = (V, E) consisting of a prescribed set V, which is suitably made up of vertices or nodes integrated with a concerned set E that is made up of edges or links, which are 2-element subsets of V.

Definition 1.2. Undirected Graph: A graph G = (V, E) is an undirected graph which is thus made up of orientation less edges. The edge (a, b) is thus observed as an identical to the edge (b, a), i.e., they are not ordered pairs.

Definition 1.3. Connected Graph: In a particular undirected graph G = (V, E), two vertices u and v are called integrated together if G is made up of a route from u to v. Otherwise, they are called disconnected. A graph thus acquires the name connected only if all the pairs contained in it appear to be in the connected form; else it would be suitably termed as a disconnected graph. Definition 1.4. Weighted Graph: A graph G = (V, E) is thus termed so only if a particular number (weight) is allotted to each of the particular edges and/or vertices. These weights have been found to exhibit certain features, for instance, costs, lengths or capacities, etc. all these representations are done with respect to the concerned problems at hand.

Definition 1.5. k-connected Graph : A graph G = (V, E) is thus termed as a k- vertex connected or k -connected provided each pair of the corresponding vertices exists for at least the k mutually independent routes aggregating them together. Else G appears to be in the connected form even after encountering the removal process of any k - 1 vertices from G.

Definition 1.6. Dominating Set (DS): For a given graph G = (V, E), a DS is a subset $D \subseteq V$, such that for every vertex $v \in V$, either $v \in D$, or v has a neighbor in D.

Definition 1.7. Connected Dominating Set (CDS): For a given graph G = (V, E), a CDS is a subset $D \subseteq V$ such that D is a DS and the graph induced by D is connected. The nodes in a CDS are called dominators, the others are called dominatees.

Definition 1.8. Maximal Independent Set (MIS): For a given graph G = (V, E), an Independent Set (IS) is a subset of nodes $U \subseteq V$, such that no two nodes in U are adjacent (ie. ¥ $(x, y) \in U$ j $(x, y) \notin E$). An IS is maximal, if no node can be added without violating independence.

Definition 1.9. Multi-Point Relay(MPR): For a given a graph G = (V, E) and a node $v \in V$, let $N^v_1$ and $N^v_2$ represent the set of 1-hop and 2-hop neighbors of v, respectively. MPR asks for a minimum size subset of $N^v_1$ such that $N^v_2$ is covered by MPR (i.e., MPR(u) = $\{v \mid v \in N^u_1\}$ such that $N^u_2 = U_{v \in MPR(u)} N^v_1$).

Definition 1.10. Maximum Degree D: Let G = (V E) be a graph. For a node $v \in V$, d(v) denotes the degree of v and $N^v_1$ denotes the neighbor set of v. $N^v_1 = \{u \mid (u, v) \in E\}$ and $d(v) = |N^v_1|$. The maximum node degree of G is, $D = \max\{d(v) \mid v \in V\}$. The problem of finding the MCDS of a given graph is known to be NP complete. Therefore, only approximation algorithms running in polynomial-time are practical for wireless ad hoc networks.

networks.

Definition 1.11. Connected Dominating Set (CDS) : A Dominating Set is connected if there exist a path between any two nodes in the set and the path only consists of the nodes in the set [56]. A Connected Dominating Set of G = (V, E) is thus considered as a Dominating Set of G in a particular way so that the concerned sub graph of G is thus induced by the concerned nodes in this set, this has been found to take the connected form.

The nodes comprised in a CDS have been preferably termed as the dominators. Those nodes apart from that of the dominators are thus termed as the dominatees. It has been clearly observed that the concerned size of a particular CDS is thus equal to the number of the corresponding dominators [55]. Each and every individual dominatee would be preferably dominated by a particular dominator [61]. As far as the CDS C is concerned, the contained nodes in C have been found to be permitted to contact the various other existing nodes in the opted set without relying on the nodes contained in V – C [62]. A maximal independent set is a dominating set.

If we connect the nodes in an MIS, it forms a CDS [60]. Another observation is that as the contained nodes in a dominating set are not adjacent to each other, these so called dominating sets cannot be considered as an MIS.

Definition 1.12. Minimum Connected Dominating Set (MCDS) : Considering all the CDSs of a particular graph G, it has been found that the node possessing the minimum cardinality factor would be essentially termed as the Minimum Connected Dominating Set (MCDS) [63].

The observed limitation of developing a MCDS is thus viewed as the NP-hard. As far as the CDS based routing strategy is concerned it has been clearly observed that the dominator nodes are most preferably involved in the process of maintaining and regulating the routing information. The process of message transmission here would essentially involve a dominator, where a particular dominatee node would transmit a message to another dominatee via a dominator. This preferably minimizes the prevailing search space within the corresponding CDS. On the other hand when the corresponding message reaches the destination's dominator, the message would be appropriately delivered to the destination via the said dominator [60].

## 2.1. APPLICATIONS OF CDS

The communication methods and network topology maintenance are challenging in MANETs and WSN, as these networks lack a fixed or pre-defined infrastructure. With reference the concepts of the fixed infrastructure in the wired type of networks, many researchers have been working on creating an effective virtual backbone in these networks.

It is possible to build a temporary fixed infrastructure called as the virtual backbone (VB) by using a CDS. A VB is thus observed as a subset of nodes capable of establishing the data communication tasks, these are further found to involve themselves in the various serving process to the nodes that lie outside the concerned backbone zone. It has been applied for the following applications: Multicasting/broadcasting [3, 4–6, 23, 26, 30, 31, 33, 37, 39, 42, 44, 50]: Broadcasting is frequently used in on demand routing protocols for route discovery.

The incorporation of the CDS nodes for the purpose of transmitting the broadcast type of packets has thus guaranteed for the complete of the concerned packets together with the elimination of the excessive broadcast redundancy factor. Routing [2, 4, 16, 17, 19, 28, 40, 41, 49, 51]: By using only nodes in the CDS as routers, non-CDS nodes do not maintain a routing table. CDS incorporation has turned the routing process simpler, further this offers the benefit of adapting to the emerging modifications in the network topology.

In addition to the above mentioned benefits it has been further observed that the incorporation of the CDS have suitably minimized the traffic related problems inside the network during the various communication processes and thus has simplified the entire existing connectivity among the various nodes of the concerned network. Energy Efficient Scheduling [48, 49, 50, and 52]: It has been found that the energy consumption level of the concerned network can be appropriately reduced by allowing the non-CDS nodes to enter into their periodical sleep mode suitably; this methodology further assists in the process of maintaining the network connectivity appropriately.

Topology Control [9, 34, 36, 35, 47]: In a largely incorporated sensor networks, the CDS introduced node coverage has been found to be a good approximation to provide reduced topology for area coverage. The incorporation thus appears to be inside the devised sensing range of the CDS nodes possessing increased levels of probability.

## 3. CLASSIFICATION OF CDS CONSTRUCTION ALGORITHMS

The CDS construction algorithms have been suitably classified into two different algorithms [59]: (a) Centralized algorithms (b) Decentralized algorithms

(a) Centralized algorithms

Knowledge about the network-wide information is essential for centralized algorithms. As compared to decentralized ones, centralized algorithms give a smaller size CDS. These algorithms assume that the complete network topology information is available, which is usually not practical as far as the mobile wireless networks are concerned. Moreover it turns out to be tedious in controlling the nodes in wireless networks from a centralized authority.

(b) Decentralized algorithms

As far as the decentralized algorithms are concerned, it is viewed that the existence of local network information is thus essential. The above mentioned algorithms have been further categorized as [59]:

(i) Distributed algorithms

(ii) Localized algorithms

As far as the distributed algorithms are concerned, the various adopted decision strategies thus appears to be decentralized in nature. On the other hand in the localized algorithms, the adopted decision strategies appear to be distributed with the additional requirement of a predefined count of communication rounds [55].

Localized CDS algorithms are classified into two different types [59]:

a) Addition-based CDS construction

b) Subtraction-based CDS construction

a) Addition-based CDS construction. The initial subset of nodes chosen by addition-based CDS algorithms is usually disconnected. These algorithms are thereafter found to append extra nodes in order to construct the corresponding CDS. With reference to the concepts of the initial subset, these algorithms have been further classified into two types: MIS-based CDS algorithms and Tree-based CDS algorithms [59].

MIS-based CDS algorithms: MIS-based CDS algorithms are two-stage algorithms. These algorithms have been found to construct the relevant CDS by means of aggregating an MIS suitably. In the initial phase, the MIS of the concerned network topology would be developed in the distributed form. The nodes thus possessing a suitable number of local neighbors would be opted initially. These selected MIS nodes form the skeleton of the CDS.

The second phase is thus viewed to involve itself in the process of aggregating the corresponding nodes within the MIS; additional nodes are added by employing a localized search. Thereby the CDS is formed.

Tree-based CDS algorithms:

In these types of algorithms, a particular subset of nodes suitably termed as the initiators would be selected in the initial stage. Then from each of these initiators, a CDS tree is constructed. These algorithms work in three different sections. In the initial phase, a stipulated number of initiators would be selected from the concerned network.

Then using the timer, each initiator grows a tree for the purpose of enabling the nodes possessing an increased number of neighbors to be appropriately appended on to the tree. In the third phase, the previously generated neighboring trees are connected by utilizing additional bridge nodes.

b). Subtraction-based CDS construction, these algorithms begin its functioning with the selected set of all nodes present in the concerned network. Then, nodes are systematically removed for the purpose of developing the required CDS.

As compared to subtraction-based CDS construction algorithms, addition-based algorithms produce smaller size CDS [59].

## 4. CDS CONSTRUCTION ALGORITHMS: A SURVEY

Connected Dominating Set (CDS) has been found to be extensively adopted in the literature for constructing the required virtual backbone structures in the ad hoc type of networks. The inbuilt details of the corresponding virtual backbone structure were initially introduced in [54]. Later, authors in [66] proposed two approximation algorithms for the CDS construction.

The first one is a greedy algorithm, for which efficient implementation is also provided. The second one is the improvement of the first algorithm. It involves finding a dominating set in the first phase and connecting the dominating set in the second phase. For efficient routing in ad hoc networks, authors in [67] present a self-organizing, dynamic infrastructure called a spine.

The authors approximate an MCDS for use as the spine. Only partial topology information at each spine node is needed by the algorithm. The proposed spine based routing is shown to yield good routes with low overhead. A distributed algorithm to construct CDS in ad hoc wireless networks is proposed in [53].

The authors employ a marking process, where all the vertices are unmarked initially. Then, through the marking process, every vertex is either marked or unmarked. All the marked vertices then form a CDS. The authors have proposed two rules which are used to further reduce the size of the CDS. Authors in [68] apply the concept of localized dominating sets to reduce the communication overhead of a broadcasting task.

To improve existing dominating sets, the authors use node degrees instead of their IDs as primary keys. The authors state that dominating set based broadcasting, enhanced by neighbour elimination scheme and highest degree key, yields reliable broadcast. Two distributed heuristics for constructing CDS are provided in [69]. Both the algorithms need only single-hop neighbourhood information.

The first one is the ID-Based algorithm, where information about own ID and IDs of all neighbours is maintained by each node. In the second algorithm known as the Level-Based algorithm, each node maintains information about its own ID and level, along with the IDs and levels of all its neighbours. Authors in [70] provide a method of constructing power-aware CDS.

It is based on a dynamic selection process, where a node with higher energy level is given preference. CDS is selected considering the node degree and the energy level. Authors in [63] focused on constructing virtual backbone for ad hoc wireless networks and put forth a distributed algorithm to construct CDS with smaller size.

There are two phases in the algorithm proposed by them. A maximal independent set (MIS) is built in the first phase and then Steiner tree is used to connect all vertices in the set. The first message-optimal distributed approximation algorithm for constructing MCDS is presented in [71].

It is a fully localized algorithm, wherein each node requires the knowledge of single hop neighbours and a constant number of 2-hop and 3-hop neighbours alone. The algorithm has been observed to comprise of two different phases. In the first phase, the MIS is constructed. The second phase comprises of connecting each dominator to all dominators within three-hop distance. The dominators and the connector nodes together form the CDS.

Authors in [72] provide distributed algorithm to construct CDS, which consists of two phases. In the first phase, MIS is constructed and in the second phase, a dominating tree is constructed, whose internal nodes become a CDS. The algorithm is shown to be message optimal. A completely localized one-phase distributed algorithm, r-CDS, for constructing CDS is proposed in [60].

It uses MIS for constructing CDS and each and every individual node has been found to rely on the knowledge of the connectivity related information within its 2-hop neighborhood. The proposed algorithm is found to construct a CDS with smaller size. A one-step greedy approximation for Minimum Connected Dominating Sets (MCDS) is provided in [73].

A distributed algorithm to construct MCDS for wireless ad hoc networks is proposed in [62]. The proposed algorithm is based on MIS and is fully localized. Knowledge of 1-hop neighbours alone is needed by every node. The authors show that the algorithm performs better with respect to MCDS size. Authors in [74] propose CDS construction algorithms that provide diameter reduced, risk reduced and interference aware dominating sets, without increasing CDS size.

They have illustrated the fact that in the development phase of the concerned CDS, certain quality related issues of the relevant dominating sets should be taken care of together with the number of nodes in the concerned network. A particular form of distributed algorithm for the development of the CDS has been introduced in [75]. The authors have been found to illustrate an enhanced analysis report regarding the existing relationship among the prevailing size of a MIS and a minimum CDS.

Authors in [64] have introduced a Timer-based Energy aware Connected Dominating Set (TECDS) protocols. There appear two different stages in the concerned TECDS: initiator election and CDS construction. Energy level at each node is considered during CDS construction. The authors state that the proposed protocols yield smaller CDS size and extend network lifetime. Authors in [76] have illustrated the development of the CDS algorithm that appears to perfectly minimize the CDS size and the corresponding computation complexity at a time.

The development of a virtual backbone for the selected ad hoc wireless networks is thus verified in [58]. The authors have been found to offer two distributed message/time efficient algorithms for the purpose of developing a minimum CDS. The first one grows a tree from a unique leader, while the opted one is initiated by multiple locally elected leaders.

Authors in [61] have been found to exhibit a self-stabilizing distributed approximation algorithm for developing the MCDS. Algorithms involved in the development of a quality CDS in terms of certain features such as the size, diameter and Average Backbone Path Length (ABPL) is thus offered in [55]. Two centralized CDS construction algorithms, viz.,

CDS-BD-C1 and CDS-BD-C2, and a distributed algorithm, CDS-BD-D, which is a distributed version of the second centralized algorithm, have been introduced. The algorithms preferably take into consideration the energy related parameters for the purpose of extending the life time of the concerned network. A Breadth First Search (BFS) tree is built and then an MIS based on the BFS tree is found. Then the MIS nodes are connected in prescribed format for developing the required CDS. The algorithm proves to be efficient in formation of a virtual backbone when compared to other previous works.

A distributed algorithm for the purpose of developing a stable CDS is proposed in [56]. The algorithm is a link-stability-based CDS-forming algorithm that tends to develop a CDS by means of retaining a node possessing numerous weak links from the task of being opted as a suitable member of CDS. The criteria used in the algorithm are: less number of danger links, lower average received power strength and smaller node identifier.

Authors in [77] have been found to offer a distributed form of local algorithm for the purpose of evaluating the CDS. The nodes contained within this network have been found to with hold information's regarding their locations. For the purpose of devising decisions locally, the authors here have been found to make use of the ordering technique, which ensures that the devised decisions entirely depends on the nodes existing within a predefined distance within the concerned network. When local computation of the CDS is done, each node that belongs to the CDS runs a local pruning test to minimize the concerned CDS size.

The authors here have been found to portray the computational efficiency and scalability of their developed algorithms. A particular form of a distributed algorithm for the purpose of developing a suitable CDS in the concerned wireless ad hoc network has been portrayed in [57]. The introduced Area algorithm has been found to take the localized form, in this type the contained nodes have been observed to be segregated into various areas and the corresponding dominators who tend to appear two or three hops away would be perfectly integrated together. Authors in [78] have been found to offer a Distributed Single-Phase CDS construction algorithm (DSP-CDS) for the ad hoc networks.

The most significant property of the introduced algorithm is that it develops the CDS in a single phase. The 1-hop neighborhood information is thus utilized by each of the individual nodes for the purpose of devising certain local decision regarding the aggregation of the dominating set. The introduced algorithm thus generates a CDS of small size.

Authors in [65] have been found to introduce a timer-based CDS protocol, in which the required number of initiators would be selected in the initial phase in a distributed manner, followed by which the timers would be adopted for the development of the CDS with reference to the obtained localized information from the corresponding initiators. With reference to the number of initiators, two different versions of the protocols have been suitably proposed, viz., Single-Initiator and Multi-Initiator. To overcome the single point of failure (reconstructing CDS when the Single-Initiator leaves the network) in Single-Initiator, the Multi-Initiator version is proposed.

The authors show that both the protocols produce CDS of competitive size. An energy efficient CDS construction algorithm has been introduced in [79]. The introduced algorithm has been found to take the distributed form, this essentially considers node's mobility and the residual energy for the purpose of producing a stable MCDS. The authors state that the proposed algorithm is good both in dense and sparse networks, and that it yields smaller size MCDS.

Authors in [80] provide a distributed CDS construction algorithm. Nodes with more energy and closer nodes are given priority while selecting the backbone nodes. This introduced algorithm has been found to extend the longevity of the concerned network and hence involves itself in minimizing the delay related problems. Another form of a centralized algorithm for the development of the CDS has been introduced in [81]. The algorithm comprises of two different phases.

In the first phase, MIS is constructed by using the sequence MIS algorithm and then the MIS nodes are connected by means of suitably appending the existing intermediate nodes in order to develop the CDS. Author in [82] proposed energy efficient optimal CDS algorithm suitably integrated with an activity scheduling mechanism based on the unit disk graph concept [UDG], this has been viewed as a distributed form of algorithm. As far as the development of a stable optimal energy efficient CDS is concerned it is observed that the corresponding node's mobility and residual energy (RE) are thus opted as the prime parameters in its development.

Author in [83] proposed a distributed strategy for the purpose of developing and maintaining a k-hop CDS in the concerned mobile ad hoc network comprising of two different classes of nodes. A particular aspect is thus found to distinguish the introduced mechanism from the existing ones, it is the specified value for the corresponding term k, and an enhanced k is thus found to offer a minimized CDS. On the other hand if this term k appears to take the increased form then the resulting CDS would essentially comprise of a single node alone.

Especially, the developed CDS appears to be increasingly robust in nature, yet would appear to be minimally affected by the prevailing modifications in the concerned topology of the mobile ad hoc network.

## 5. CONCLUSION

The lack of predefined routers and physical infrastructure in ad hoc networks makes routing difficult. If flooding of messages is used to overcome the problem, it results in broadcast storm problem.

So, the concepts of the virtual backbone type of architecture have been introduced in the literature, in the form of a viable solution for the purpose of commemorating the routing aspects in the concerned ad hoc networks. One of the well-known approaches involved in the development of the virtual backbone is CDS. This paper focused on the various existing CDS algorithms for virtual backbone construction in ad hoc networks.

A study based on the obtained comparative results related to the development of the CDS has been suitably offered. It is observed that the algorithms proposed for CDS construction are largely distributed ones, as distributed algorithms fit well with the working of the ad hoc networks. Most of the solutions involve two phases for CDS construction. The major performance metric that has been considered is the size of the CDS.

As part of future research, CDS maintenance algorithms that target adaptability of CDS to network topology modifications could be explored. The use of CDS in the form of a virtual backbone structure in the specific routing protocols could also be examined in the future.

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