IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-10, Oct 2018 E-ISSN: 2347-2693

Power Efficient Routing in Mobile Adhoc Network (MANET) Using Connected Dominating Set

B. Kalita[1*], A. K. Das[2], A.U. Islam[3]

[1]Dept. of Computer Science &IT, Assam Don Bosco University, Azara, Guwahati-781017, Assam, India
[2]Dept. of Computer Application, GIMT Guwahati-781017, Assam, India
[3]Dept. of Computer Science and IT, Cotton University, Guwahati-781001, Assam, India

Corresponding Author: arnab_kumar@gimt-guwahati.ac.in Tel: 9435145017

Available online at: www.ijcseonline.org

Accepted: 13/Oct/2018, Published: 31/Oct/2018

Abstract: In this paper, we propose a new algorithm to find a minimum Connected Dominating Set(CDS) of Mobile Adhoc Network(MANET) modelled as a unit disk graph. The new algorithm known as New Connected Dominating Set(NCDS) reduces the number of message that needs to be broadcasted and thereby saving time and elongating lifetime of the network and also supports dynamic topology of the network. Further important theorems of Unit disk graph of the form (2n+8, 6n+14), having degree ($1\leq deg \leq 6$) for $n \geq 1$ have been proposed and proved.

Keywords: Mobile Adhoc Network (MANET), Connected Dominating Set (CDS), Unit Disk Graph (UDG).

I. INTRODUCTION

A mobile ad hoc network (MANET) is defined as a collection of mobile hosts that dynamically form a wireless network without any backbone infrastructure and centralized administration. Each device in a MANET is a router and is free to move independently in any direction and forward traffic even if it is not related to its own used. MANET is basically an organizationless network of transportable devices and wireless communication capabilities that can be joined together at any time and at any place dynamically.This type of network mobile hosts, sometimes, simultaneously acts as a router, are connected to one another by wireless links and can be moved easily and randomly. It is interesting to note that due to the changing topology an autonomous system without any base station is generated. In MANET each node has limited transmission range for which packets are forwarded from any initiating node to a destination node in a network with the help of multiple hopes. Since it does not have any fixed structure and centralized control, any node can leave or join the network at any time. For a smooth data transmission, nodes can send and receive data in a protected manner. If the node lies in the transmission range then these nodes can easily transmit data, however if the nodes are not in each other's transmission range then such networks follow the concept called multi hop data transmission, where intermediate nodes provides a route from source to destination. Various protocols have been designed for route discoveries from source to destination. With this changing topology route discovery is a major challenge in MANET. Mobile ad hoc networks can be used in many applications, ranging from sensors for environment, vehicular ad hoc communications, road safety, health, home, peer-to-peer messaging, disaster rescue operations, air/land/navy defence, weapons, and robots.

Since the node does not have any information where to route the packet MANET operates on the concept of flooding where each host, after receiving a message, broadcasts it to the entire network. Due to this network bandwidth and battery power of the devices may be wasted. Moreover messages may become duplicated which increases the load on the network bandwidth and also extra processing needs to be done to discard the duplicate messages. One of the greatest challenges in forming this type of network is to involve the minimum number of nodes (hosts) in the routing process because not every node in the network may be required to forward the messages. One way to solve this problem is to identify Minimum Connected Dominating Set (MCDS) among the hosts in a given area. A Dominating Set (DS) is a subset of nodes of a network such that every node that is not in the DS is directly connected to at least one member of DS. A Connected Dominating Set (CDS) is defined as a set of nodes in a network such that each node is either in the set or adjacent to a node in the set. In addition, every node in a CDS should be able to reach every other node in the CDS by a path that stays entirely within the CDS. Since the dominating set nodes covers the entire network so it can be used as a backbone for routing in MANET. Use of dominating set in routing not only provide efficient routing but also elongate the lifetime of the network. In a MANET, when the size of the CDS is small the message overhead is also less.

This paper is organised as follows: In section I the introductory works related with mobile adhoc network is presented. In section II, some related works have been studied relating to the existing algorithms to find CDS in mobile adhoc network .The definitions of different concepts used in this paper is given in section III. In section IV, we propose a new algorithm to find CDS in a mobile adhoc network modelled as a unit disk graph. In section V, we implemented our algorithm in an unit disk graph of 12 vertices .In section VI, we have analysed the result of executing our proposed algorithm on an unit disk graph of different number of vertices and edges and proposed three important theorems on the size of CDS nodes and the total degree of the CDS nodes for a specific form of unit disk graph. In Section VII we address the challenges of node mobility and topology change of mobile adhoc network and proposed two algorithms named as MOCDS (Modified Connected Dominating Ser) algorithm and RCDS (Repaired Connected Dominating Set) algorithm to find the CDS in case of change in topology of the network. In section VIII, we have given the conclusion and future scope of this work.

II. RELATED WORK

In Mobile Adhoc Network the lifetime of the network depends on the lifetime of the nodes in the network. In order to improve the lifetime of the network we must use the nodes efficiently. The nodes are involved in the process of routing and it is found that when less number of nodes are involved in routing then it increases the lifetime of the network. So it is always desired that minimum number of nodes are involved in the process of routing. To implement this idea the concept of connected dominating set(CDS) of a graph is used in Mobile Adhoc Network for routing through the network. The connected dominating set is a widely used concept for routing in MANET.Various algorithms were proposed to find the CDS in a graph that can be used in the routing purpose. Algorithms for CDS construction are divided into two categories: 1) Centralized algorithms that depend on global topology information 2) Decentralized algorithms that depend on local topology information only. But all these algorithms requires significant message overhead in constructing the CDS. Most of the algorithms proposed till now assumes a known topology of the network which is practically impossible in MANET due to node mobility.

The first major work in the area of CDS construction had been proposed by Guha and Kuller [1] who proposed two greedy Heuristic algorithms. The first heuristic finds a CDS whose size cannot exceed 2(1+H(⌂)).|OPT| where ⌂ is the maximum degree of the input graph, H is the Harmonic function and OPT is the Optimal Solution. The second heuristic finds a CDS of size (3+ln (⌂)).|OPT|. All these heuristics uses the concept of colouring of graph. Another Heuristic algorithm were proposed by X. Yan , Y.Sun,Y.Wang [2] where they calculate the minimum connected dominating set with maximal weight. It has been tried to ensure thatt most suitable nodes are selected as the CDS nodes. Besides,O. Chaturvedi, P. Kaur, N. Ahuja, Toshima Prakash [3] proposed a distributed algorithm for construction of CDS in a MANET. The proposed algorithms organize the entire network topology into clusters and the CDS is formed out of the nodes acting as the cluster heads (CHs).

Recently K.G. Preetha, A. Unnikrishnan[4] proposed to enhance the utilization of dominating nodes and it has been focused to find all possible dominating sets in the graph and then used them one by one based on their reliability. S. Vinayagam[5] highlighted the various CDS construction algorithms that have been put forth in the literature. A comparison of the major works relating to CDS construction is provided, emphasizing the type of algorithm, technique employed, performance metric used and the outcome achieved. Another new approach has been put forwarded by Preetha K G, A Unnikrishnan[6] for finding the route using dominating set that reduces reroute establishment delay and increase the packet delivery ratio. K.Islam, S.G, Akl, H..Meijer [7] proposed an algorithm for finding disjoint dominating set that can be used for routing. B.Yin, H. Shi, Yi. Shang [8] proposes a single phase distributed algorithm for constructing a connected dominating set. Each node uses one-hop neighbourhood information and makes a local decision on whether to join the dominating set. Each node bases its decision on a key variable, strength, which guarantees that the dominating set is connected when the algorithm converges. J. Wu, H. L. Li [9] proposed a CDS protocol that consists of two phases. During the first phase, each node collects two-hop neighboring information by exchanging messages with its one-hop neighbors. If a node finds that there is a direct link between any pair of its one-hop neighbors, it removes itself from the CDS. In the second stage, two additional rules are applied to further reduce the size of the CDS. B. Chen, K. Jamieson, H. Balakrishnan, and R. Morris, [10] proposed an algorithm (SPAN) to select specific nodes as the coordinators. These coordinators thereby form a CDS and let the other nodes go into low power mode thus saving energy.M Avula,S Moo Yoo,S Park[11] proposes a novel algorithm for constructing the CDS and claims it to be less expensive in terms of message complexity.

Most of the works on the use of dominating set for routing in MNAET uses one or two hop information of the node and involves two phases for construction of CDS nodes. Moreover the algorithms proposed are decentralized that generate a huge number of messages thereby unnecessarily consume large network bandwidth. Another limitation is that if the topology of the network changes then the CDS has to be reconstructed again from the beginning.

Our proposed algorithm addresses the aforementioned limitations and provides a reliable and efficient mobility handling scheme with significantly reduced message overhead without requiring the two hop neighbouring information. The proposed approach consider two nodes at the same time having maximum and minimum no of neighbourhood and thus quickly exhausting the network .Moreover the mobility handling is also supported by the proposed approach.

III. DEFINITIONS

We now reminds the definitions of Unit Disk Graph (UDG), Dominating set (DS), Connected Dominating Set (CDS) and other related concept that will be used later.

III.I UNIT DISK GRAPH

Unit disk graph is a 2-dimentional plane graph that for *u*, *v* € *V*, there is a bidirectional edge between *u* and *v* , if and only if *Eudist*(*u*,*v*) ≤ 1 . Here, *Eudist*(*u*,*v*) is the Euclidean Distance between *u* and *v* .

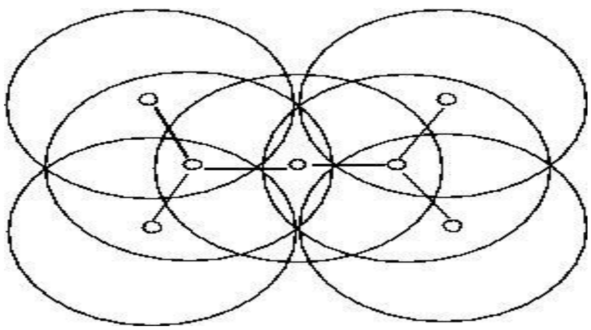

Fig 1: An Unit Disk Graph

III.II DOMINATING SET

Given a graph G = (V, E), a Dominating Set (DS) of G is a subset C ⊂ V such that each node either belongs to C or is adjacent to at least one node in C. In other words, a Dominating Set of a graph G = (V, E) is a set of nodes V/ such that ∀ (v, w) ∈ E, v ∈ V/ or w ∈ V/. A Vertex Cover refers to a set of vertices that cover all the edges, whereas a Dominating Set refers to a set of vertices that cover all the vertices. Fig 2 is an example of a dominating set.

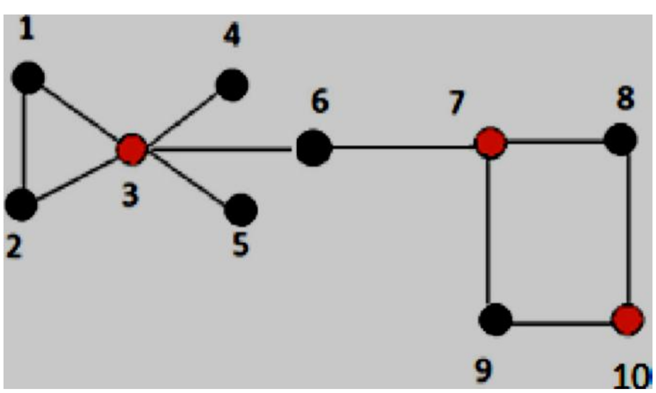

Fig 2: A dominating set (3,7,10)

III.III CONNECTED DOMINATING SET

In an undirected graph *G* = (*V*,*E*) which consists of a set of vertices *V* ={*n*1, . . . *nk*}, and a set of edges *E* (an edge is a set *{ni,nj}*, where *ni,nj € V* and *ni ≠ nj*) a set *D* ⊆ *V* of vertices is called a *dominating set* (DS) if every vertex *ni € V* is either an element of *D* or is adjacent to an element of *D*. If the graph induced by the nodes in *D* is connected, we have a *connected dominating set* (CDS).

III.IV MINIMUM CONNECTED DOMINATING SET (MCDS)

Among all CDSs of a graph G, the CDS with minimum cardinality is called a Minimum Connected Dominating Set (MCDS).

IV.PROPOSED ALGORITHM TO FIND CDS IN MANET

Input: A Graph G (V,E)
Output: A connected Dominating Set (CDS)
Symbols used in the algorithm:
V – Set of vertices or nodes.
E – Set of edges or connection between the nodes.
N(V) –Set of neighbouring vertices of V.
|N(V)| - Number of neighbouring vertices of V.
Color(v) –Color of vertex v and it may be Black, Grey and White.
Color(N(v)) –color of neighbouring vertices of v.
Initially: N(V)=0 and CDS=NULL.

Algorithm: NCDS (G)

1. For ∀ v *in V*
2. Broadcast a packet containing N(v) and and vi(node id) to all node in the network.
3. Arrange the vertices in V in decreasing order of |N(V)| and we get
$$V= \{v_1,v_2,v_3,\ldots\ldots v_{n-2},v_{n-1},v_n\}$$
where v_1 is the vertex having the maximum number of neighbours and v_n is the vertex having the minimum number of neighbours.
4. For ∀ v *in V*
5. Color(v)=White
6. For ∀ v *in V*
7. while (Color(v)=White)
8. Color(v_1) and Color(v_n)=Black
9. Color(N(v_1))and Color(N(v_n))= Grey
10. Repeat step 8 to 9 for (v_2 and v_{n-1}),(v_3 and v_{n-2}) and so on until no more white node is left.
11. For ∀ v *in V* where color(v)=Grey
12. If |N(v)|≥2 and color(N(v))=Black
13. Color(v)=Black
14. For ∀ v *in V* where color(v)=Black
15. If |N(v)|≥2 and color(N(v))=Black
16. If all neighbour of v is not present in the neighbouring set of the two open black nodes

17. Then CDS=CDS U {v}
18. Else Discard v from CDS.

V. ILLUSTRATION OF THE PROPOSED ALGORITHM IN A UNIT DISK GRAPH

Now let us implement the algorithm on the following unit disk graph (Fig 3) of 12 vertices.

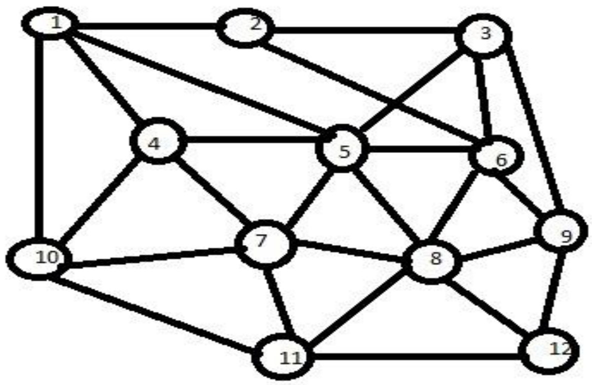

Fig 3: An unit Disk graph of 12 vertices

The algorithm starts by broadcasting a packet that contains the number of neighbour (initially zero for each node) and a node ID. After execution of this step the following information about one of neighbour of the node is obtained.(Table 1)

Table 1: One hop neighbour of the nodes

Node	**Neighboring nodes *N*(*i*)**	**Number of neighboring nodes**
1	2,4,5,10	4
2	3,6,1	3
3	2,5,6,9	4
4	1,10,7,5	4
5	1,4,3,6,7,8	6
6	2,3,5,8,9	5
7	4,5,10,8,11	5
8	5,6,9,7,11,12	6
9	3,6,8,12	4
10	1,4,7,11	4
11	10,7,8,12	4
12	11,8,9	3

Now after execution of step 2 which arrange the nodes in decreasing order of the numbers of neighbours they have, we get

V = {5, 8, 6, 7, 1, 3, 4, 9, 10, 11, 2, 12}.

Now all the nodes in V are initialised to white color and the graph in fig 4 is obtained

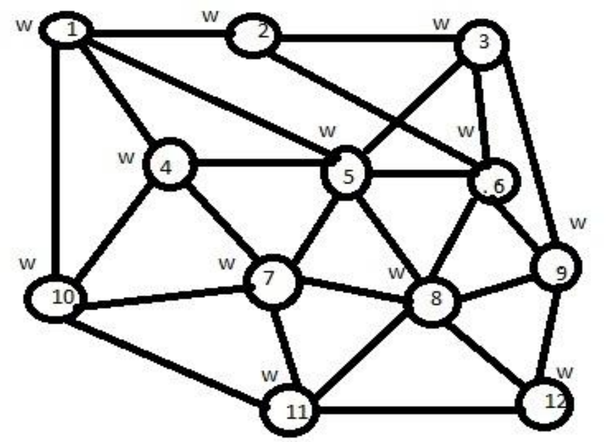

Fig 4

Now we change the color of node 5 and 12 to black and its neighbours are made grey and we obtain the following graph in Fig 5

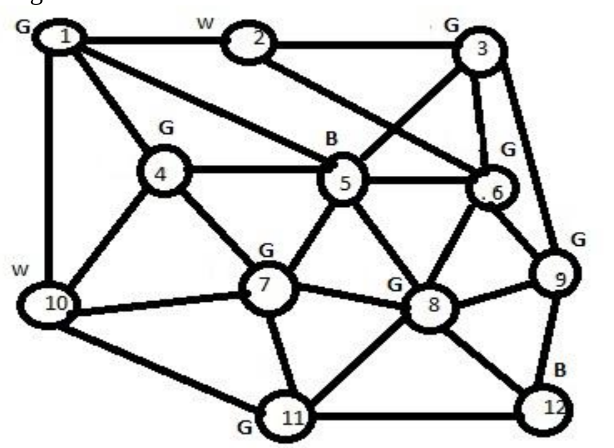

Fig 5

Next we repeat the same step in node 8 and 2 and make node 2 black in color. Node 8 will remain unchanged as it is already grey in color. Then we make the neighbouring node of 2 as grey and we obtain the following graph fig 6

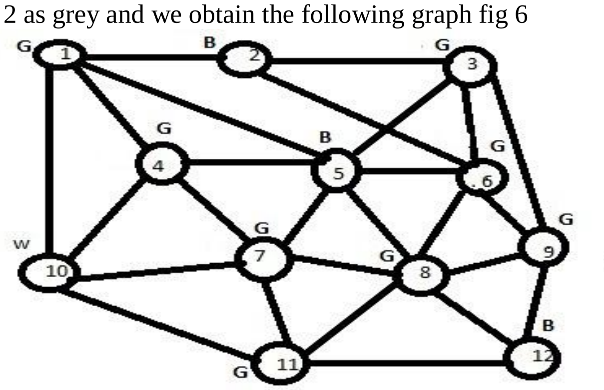

Fig 6

Node 6 and 11 are already grey in color so the graph will remain unchanged.

Next we made node 7 and 10 black and its neighbours grey. Node 7 will remain unchanged as it is already grey in color.The following graph (Fig:7) is obtained after applying the step

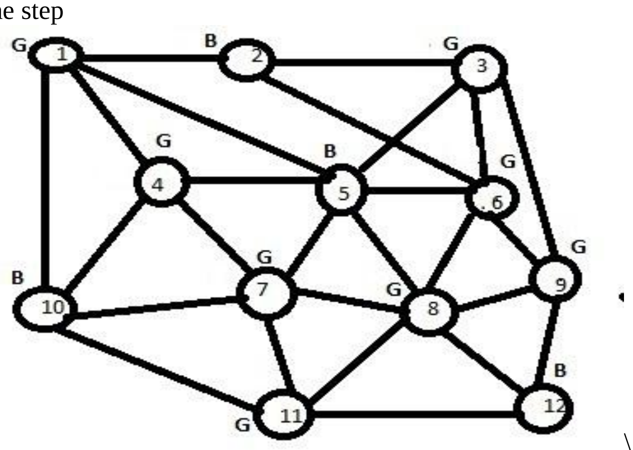

Fig 7

Now for the grey node in the graph if it has two open black neighbours then we change it to black. The grey node which does not have at least two open black neighbour will remain as it is. The result of the execution of this step is given in the following table 2 and the resultant graph fig 8 is obtained.

Table 2

Grey node	Two Black open neighbour	Change color to black ? (Y Or N)
1	2,5	Y
3	2,5	Y
4	5,10	Y
6	2,5	Y
7	5,10	Y
8	5,12	Y
9	Nil	N
11	10,12	Y

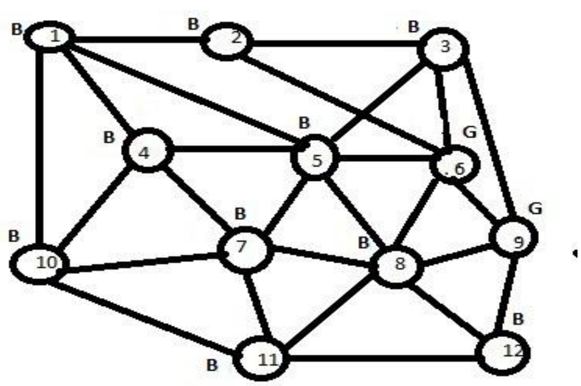

Fig: 8

Now for each black node if all its neighbours are not present in the neighbouring set of two open black neighbours then it is included in CDS otherwise it is discarded. The following table 3 shows the result of this test and construct the CDS.

Table 3

Black Node	Two black open neighbour set	Neighbouring node which is not present in either of the two black open neighbour	CDS node? (Y or N)
1	2,10	5	Y
2	1,3	Nil	N
3	2,5	9	Y
4	(10,5),(1,7)	Nil	N
5	1,3	8	Y
6	(2,8),(3,8), (2,9),	Nil	N
7	(10,5),(4,11) (10,8),(4,8)	Nil	N
8	7,12	6	Y
10	(1,7),(1,11),(4,11)	Nil	N
11	(10,8),(10,12), (7,12),	Nil	N

Thus the CDS is {1, 3, 5, 8}

VI.OBSERVATION

We have initially implemented our algorithm on an unit disk graph of 12 vertices and to check the efficiency of our algorithm we have taken the example of Unit disk graph (UDG) which was considered by M Avula, S Moo Yoo, S Park [1] to find the connected dominating set and apply our algorithm on the same UDG and it was found that our algorithm take less iterations to find the CDS compared to the algorithm developed by M Avula,S Moo Yoo,S Park[1].
The algorithm is implemented on an Unit disk graph of 10, 12, 14 and 16 vertices and the following results are obtained (Table 4)

Table 4: Result of executing algorithm NCDS

No of node in the Unit disk graph	No of node in CDS	Total Degree of the nodes in CDS
10	3	14
12	4	20
14	5	26
16	6	32

Thus we can conclude that a structure of unit disk graph G (2n+8, 8n+10) for n≥1 having minimum degree 1 and maximum degree 6 i.e ($1 \leq deg \leq 6$) satisfy our algorithm.

We now have the following theorems which are important for finding CDS of an UDG.

Theorem1: An Unit Disk Graph (UDG) of the form (2n+8, 6n+14) for n≥1 and having degree (1≤ $deg \leq 6$) always has a Connected dominating set of size n+2.

Proof: We prove the theorem in reverse way that if out of 2n+8 vertices for n≥1 the vertices which are not in the dominating set is adjacent to any of the n+2 vertices then it will imply that there are exactly n+2 vertices and those are actually the size of the connected dominating set. Let us assume that the theorem is true for n=1. Then n+2=3 is the size of dominating set and there are seven other vertices which are adjacent to any of the three vertices. Now as 3 vertices of the dominating set are connected then we must get a structure as shown in figure 9 and 10 below..

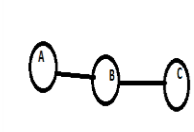

Fig 9

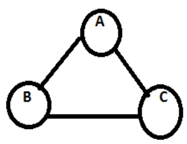

Fig 10

Now if the vertices are connected [Fig 10] then degree of each node is 2. Besides, we know that the maximum degree of any node as stated in the theorem1 is 6and so any of the three node A,B and C can be adjacent to another 4 nodes or less than that and then we get a structure as in figure11

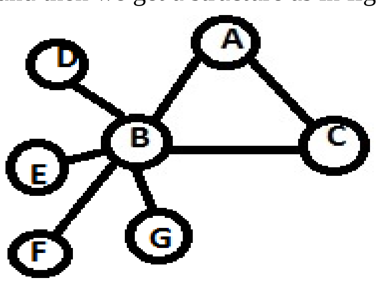

Fig: 11

Thus from Fig 11 it is quite obvious that 4 vertices are already covered by the dominating set and the remaining three vertices can be adjacent to other CDS nodes A and C as it cannot be adjacent to B because the maximum degree of any node cannot exceed 6. Thus to the CDS nodes A, B and C, remaining 7 nodes of the graph are adjacent. Thus for n=1 this is true. Now if we can prove that it is true for any value of n then our theorem holds true. Here 2n+8 is the total number of vertices and n+2 vertices are in Connected dominating set. So the number of node not in the dominating set is equal to (2n+8) - (n+2) which is n+6. If we can prove that the non dominating n+6 vertices is adjacent to any of the n+2 dominating vertices then our theorem holds true.

We know that for any positive value of n ,$n \geq n-1$. As the theorem is true for n=1, hence if we suppose that the theorem is true for n=k then we have to show that it is true for n=k+1. Now we put n=k+1 in (2n+8, 6n+14) , then there are k+7 nodes which are not in the connected dominating set. Thus for different values of n and k we have

n=1 implies vertices not in CDS is n+6=7 or k+7 when k=0

n=2 implies vertices not in CDS is n+6=8 or k+7 when k=1

n=3 implies vertices not in CDS is n+6=9 or k+7 when k=2

n=k+1 implies vertices not in CDS is k+1+6=k+7 when k= n-1.Thus it shows that

$$n \geq n-1$$
$$k \geq k-1$$
$$k+1 \geq k$$

Thus according to induction method, it is proved that for any value of n, there are n+2 vertices in the CDS.

Theorem 2: In an Unit disk graph of the form (2n+8, 6n+14) for n≥1 and having degree (1≤ $deg \leq 6$) , a node x having the maximum degree will always be one of the node in the connected dominating set.

Proof: Since the algorithm NCDS as stated in section [IV] arranges the node in the graph based on their number of neighbours, so it is always going to include the node having the maximum degree as the CDS node. Thus it is quite obvious that the node having the maximum degree will always be one of the node in the dominating set.

Theorem 3: The total degree of the nodes in the connected dominating set of an Unit Disk graph (UDG) of the form (2n+8,6n+14) for n≥1 and having degree (1≤ $deg \leq 6$) is 6n+8

Proof: We have for n=1 the total degree of the nodes in the connected dominating set of an UDG G (10,20) is 14.

Now by Theorem 1 which states that the size of the CDS of the UDG (2n+8, 6n+14) for n≥1 and having degree (1≤ $deg \leq 6$) is n+2. So the CDS is 3.Let v_1, v_2 and v_3 are the vertices in the CDS and let x1, x2and x3 are degree of corresponding vertices. Therefore $x1 + x2 + x3 = 14$..Also by Theorem 2 which states that a node x having the maximum degree will always be one of the node in the connected dominating set. So the maximum degree of a vertex cannot exceed 6. So let us assume that vertex v_1 is having the maximum degree. So x1=6.

We have $x1 + x2 + x3 = 14$
$$6 + x2 + x3 = 14$$
$$x2 + x3 = 8$$

Now it is quite obvious that node v_1 having degree 6 so it will cover 6 vertices or it is adjacent to six vertices out of the total 10 vertices (for n=1). So remaining four vertices will be covered by the other two vertices having degree x2 and x3.Here x2 and x3 can take any values from 1 to 6 but their summation should be equal to 8.So the possible values of x_2 and x_3 can be as follows x2 =2and x3=6, x2 =3and x3=5, x2 =4and x3=4, x2 =5and x3=3, x2 =5and x3=3, x2 =6and x3=2.Now for all the combinations of the degree of x2 and x3 it will definitely cover the remaining four vertices and hence the total degree of the node in CDS will not exceed 6n+8 .

VII. CHALLENGES OF NODE MOBILITY AND TOPOLOGY CHANGE

In Mobile Adhoc Network battery power of the node is the main issue to be considered. Each node in the sensor network gets deactivated due to power constraints and low energy level. As a result of which the topology of network is also changed. To handle this topology change (resulted due to addition or deletion of a node) a new CDS should be constructed. In this section we proposed two algorithm named as MOCDS (Modified Connected Dominating Ser) algorithm and RCDS(Repaired Connected Dominating Set) algorithm to find the CDS in case of change in topology of the network.

VII.I Algorithm: MOCDS (G,n)

/* Here n is the new node detected in the network*/

1. If n∈ N(v) where v.color=black and v∈ CDS
2. Then n.color=Grey
3. CDS will remain unchanged.
4. If n∈ N(v) where v.color=black and v ∉ CDS
5. Then n.color=Grey
6. CDS=CDS ∪ {v}
7. If n∈ N(v) where v.color=Grey
8. v.color=black
9. n.color=Grey
10. CDS=CDS ∪ {v}
11. Exit

VII.II Algorithm: RCDS(S, d)

/* Here S is the sub graph of G that is to be considered for CDS Construction and d is the deleting node*/

1. If d ∉ CDS
2. For the CDS node x which to which d is connected
3. T=N(x)-d
4. For ∀ q in T
5. If q ∈ N(CDS) , where N(CDS) is the neighbouring nodes of the CDS nodes
6. Then CDS=CDS - x
7. Else
8. S=N(d)
9. For ∀ x in N(d)
10. If x ∈ CDS
11. S=S ∪ N(x)
12. Call NCDS(S)
13. CDS=∪CDS

The description of the above two algorithms are given with the help of following cases and is illustrated with the help of some example.

Algorithm: MOCDS (G,n)

If a new node is detected in the network then a new CDS is formed when necessesary.

Case 1: If the new node detected is a neighbour of any of the black node in CDS then mark the color of the new node as grey and CDS will remain unchanged.

Case 2: If the new node detected is a neighbour of a black node which is not in the CDS, recompute CDS by including the black node into CDS which is the neighbour of new node. The new node is to be marked as grey.

Case 3: If the new node detected is a neighbour of a grey node then change the grey node to black node and include it in the CDS and mark the new node as grey.

Algorithm:RCDS(S,d)

If any node in the network leaves the network, a new CDS will be formed.

Case 1: If a non CDS node (a grey node leaves the network) then we have to see whether the size of CDS can be reduced or not because of this topology change.

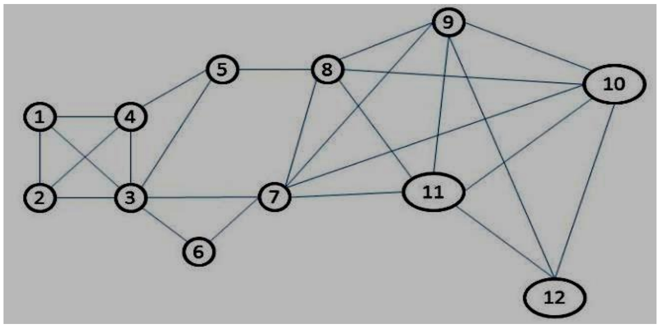

Fig 12: A network with CDS (3, 7, 9)

For example in fig 12 the CDS consists of node 3,7& 9.Now here if node 12 left the network the CDS can be reduced to(3,7).This is because all the neighbours of node 9 are also neighbours of node 7.

So this CDS will cover the entire network and we will get the following network in fig 13

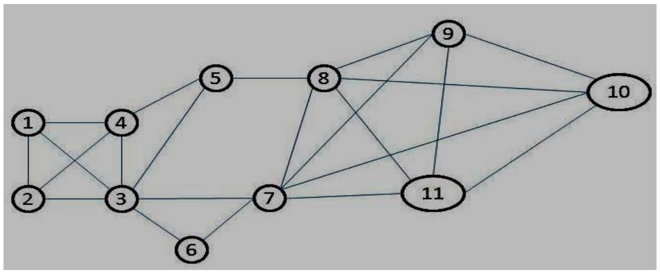

Fig13: CDS changed to 3-7 after node 12 left the network

Case 2: If a node in the CDS leaves the network then instead of recomputing the CDS from the very beginning we consider only those nodes which are neighbour of the deleting node. Moreover if among the neighbour of the deleting node any CDS is node is present then their neighbour is also included in the graph which will be considered for recomputation of CDS.

Let us consider the graph G(V,E) Fig 14 modelled as a network. Let a node v gets deactivated from the network because of low energy level or some other reasons. Due to this the CDS has to be recomputed. Here CDS is recomputed by combining a set of nodes say $V^{/}$ and previous CDS nodes. The process can be illustrated with the help of the following example.

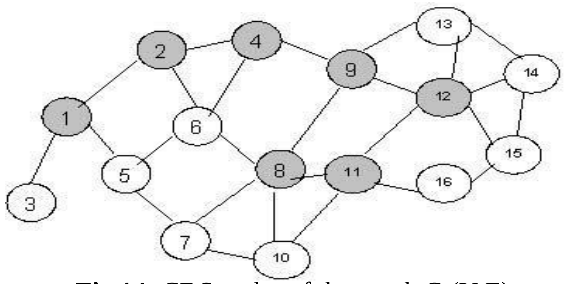

Fig 14: CDS nodes of the graph G (V,E)

Let {1,2,4,9,12,11,8} is the connected dominating set of the graph G(V,E) after applying the proposed algorithm. Let node 9 is deactivated from the network and we get fig 15

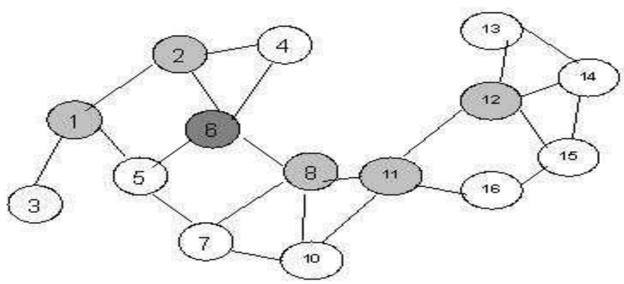

Fig 15: Graph after deletion of node 9

Now let us calculate the neighbours of inactivated node (node 9) and we get *N* (9) = {4, 8, 12, 13}. These nodes are included in set V'. Apart from that, node 4, 8, and 12 are CDS nodes, so nodes in *N*(4), *N*(8) and *N*(12) are included in set V' and we get V' = {2, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15}.So we obtain the following graph in fig 16 which will be considered for recomputing the CDS.

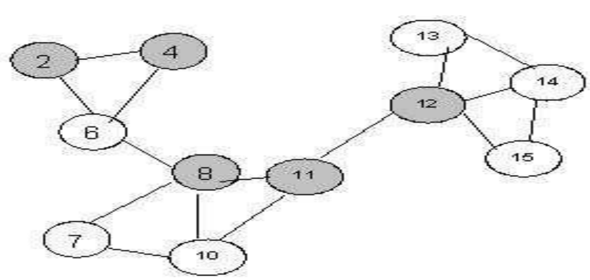

Figure 16: Graph to be considered for Local Repair

Considering the graph shown in Figure **16**, CDS is constructed such that previous CDS nodes remain intact. Resulting graph is shown in Figure 17. CDS of above graph includes nodes {2, 4, 6, 8, 11, and 12}. Node 6 is newly added CDS node. Combine this CDS with previous CDS result in a graph as shown in Figure 18

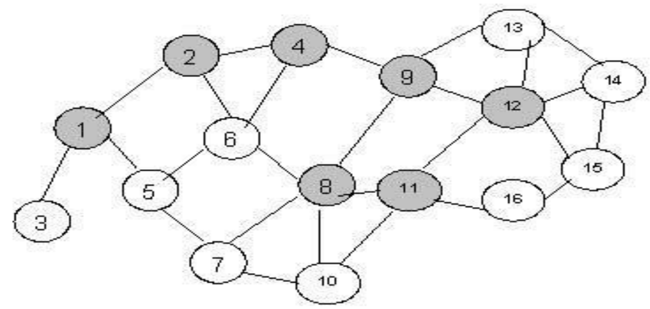

Fig:17: Graph with partial CDS

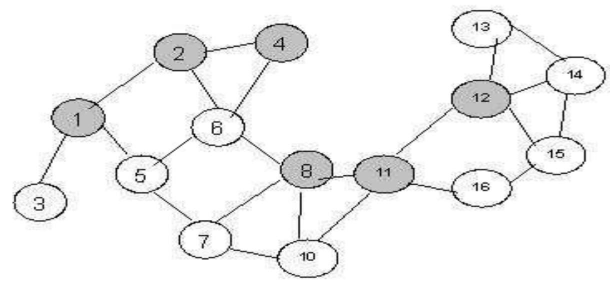

Fig: 18: Final graph of MCDS after local repair

VIII. CONCLUSION

In this paper we have presented an efficient algorithm for CDS construction in mobile adhoc networks modelled as a unit disk graph. The proposed algorithm is efficient in terms of message complexity and its ability to adapt to dynamic topologies of MANET. Three important theorems on the size and total degree of the nodes in CDS are proposed for a specific form of Unit disk graph. However the application of these theorems is yet to be find out. In future we will try to find application of these theorems on dominating set not only in routing in MANET but also in some other domain such as cryptography, machine learning and graph databases.

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Author's Profile

Bichitra Kalita , retired HOD and Associate professor , Assam Engineering College, Guwahati, now working as Professor , Dept of Computer Science Engineering & IT, Assam Don Bosco University, Azara, Guwahati, Assam. He has altogether published 56 research paper in national and international journals in various fields of mathematical and computer science. He supervised 9 scholars who have obtained their Phd degree from Gauhati Univesity in different fields. He used graph theoretic techniques to solve the long standing Goldbach conjecture in 2013.His research interest is graph theory, NP-complete problems, Graph Data base etc.

Arnab Kumar Das is currently working as an Assistant Professor in the Department of Computer Application, GIMT Guwahati and is also a research scholar under faculty of Engineering, Gauhati University, Gauhati, Assam. He has completed his Master degree (MCA) from Dibrugarh University in 2007 and M Tech (IT) from Gauhati University in 2014. His research interest is Graph theory, Algorithms and Network. He has 10 years of teaching experience.

A.U. Islam completed his Masters in Computer Application from Dibrugarh University of Assam, India. He obtained his Ph.D. in Computer Science and Engineering in 2018 from Gauhati University and currently working as Assistant Professor in Department of CSIT, Cotton University of Assam, India. He has published multiple research papers in reputed international journals including Scopus and ACM Digital Library. His main research work focuses on Graph Theory, Data Mining and Networking based education. He has 10 years of teaching experience and 7 years of research Experience.

