Dynamically Miticating Flooding Overhead and Automatic Repairing for Mobile Ad Hoc Networks

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ABSTRACT---- ***Broadcasting is a key operation in on demand route discovery for Mobile Ad hoc Networks (MANETs) to transmit a message (data packet) from the host (source) node to the rest of the network nodes. Flooding is the simplest mechanism for broadcasting. But it is usually costly and results in serious redundancy, contention and collisions in the network. The broadcast problem is reduced by different flooding techniques. CDS is one of the flooding techniques, used to reduce the broadcast storm problem, where the searching space for a route is reduced to nodes present in the set. The proposed protocol Stable Connected Dominating Set (SCDS), provides the solution to the broadcast storm problem during the route discovery phase, using a Connected Dominating Set based on the rate of change of displacement and signal strength. It predicts the new distance, using the velocity of the nodes and current position after a time period t. The predicted distance is checked whether it is in the favorable or unfavorable communication range, by calculating the signal strength. The RREQ packets are broadcast only through the CDS members, and hence the broadcast storm problem is reduced. Extensive simulations showed that the proposed algorithm, as compared to MaxD_CDS and MaxV_CDS, has a significantly long lifetime and requires less number of control packets for route discovery.***

Keywords--- Connected Dominating Set; Stable Connected Dominating Set; weight value; displacement; signal strength;

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1. INTRODUCTION

A wireless network could be one of two types: infrastructure network and ad hoc network. A mobile ad hoc network (MANET) consists of a set of mobile hosts that communicate with each other using multi-hop wireless links, and requires no stationary infrastructure, such as a base station. Each node in the network can act both as a host and a router, forwarding data packets to other nodes [1]. Conventionally, most on-demand route discovery methods employ the flooding technique, where a mobile node blindly rebroadcasts a route request (RREQ) packet until a route to the destination is established. However, this approach often results in serious redundancy, contention and collisions in the network, as well as attracting large overhead, a problem widely referred to as the "broadcast storm". To overcome this problem, several new broadcasting techniques have been proposed such as, among others, the probability-based method, area-based method and neighbor knowledge-based method.

In this study, an algorithm is proposed that looks for a more stable route by selecting dominator nodes (Connected Dominating Set) based on weighted value and which is stronger. In the weighted value algorithm, a node having minimum velocity and maximum signal strength is selected as a dominator node. The algorithm also reconstructs the Stable Connected Dominating Set (SCDS) using the neighborhood information on account of link failure.

The rest of the article is organized as follows. Section 2 discusses the related works. Section 3 presents the proposed algorithm. Section 4 describes the simulation environment and analysis. The final section presents the conclusion.

2. RELATED WORKS

A simple and efficient distributed algorithm to construct a Connected Dominating Set (CDS) was proposed by Wu & Li (2). The dominating set is any node in the network that either belongs to the set or the direct neighhour of some node in the set. CDS is used to limiting the broadcasting nodes to those gateway nodes, and hence, the broadcast storm problem is solved. Wu & Li (3) determined the connections of nodes by their geographical distances. They also provided a solution if the topology of the network changes dynamically, by an update/recalculation algorithm for the connected dominating set. Wu (4) modified the dominating set algorithm, and developed an extended Dominating-Set-Based Routing in Ad Hoc Wireless Networks with Unidirectional Links.

The CDS construction procedure proposed by Wu & Li (2) was modified by Stojmenovic et al (5) to reduce the broadcast storm problem. In this procedure, they constructed the Connected Dominating Set by taking the maximum number of neighbor nodes as the dominator nodes**.** This significantly reduces the size of the dominating set, and hence, the broadcasting nodes are limited.

Natarajan (6) proposed a Minimum Velocity-based CDS (MinV_CDS) algorithm to determine slow-moving nodes. The algorithm can determine a CDS having a significantly longer lifetime, as compared to that identified by the maximum density-based MaxD_CDS algorithm. Recently, Natarajan & Michael (8) proposed an algorithm to determine a stable CDS using the notion of a strong neighborhood (SN). They observed the SN_CDS (TNDR < 1) to have a significantly longer lifetime than a maximum density-based CDS (MaxD_CDS with TNDR = 1.0). Pervis & Natarajan (9) proposed an algorithm to determine a stable CDS, based on the predicted Link Expiration Time (LET). They constructed the CDS based on edge weights represented by the predicted link expiration time. Rajendra & Anand (10) proposed an algorithm based on the computation of an Articulation Point (AP) in an Undirected Graph. They improved Guha & Khuller's algorithm with the addition of the AP concept.

A Minimum Spanning Tree with weight value was proposed by Seiven & Ruay-Shiung (11). The weight value of each node is calculated, and a node with the highest weight value is selected as a dominator node; then, the shortest paths between the dominators are established. All nodes in the MST form the CDS. This algorithm has been found suitable for both static and dynamic environments. Ramalakshmi & Radhakrishnan (12) proposed an energy-efficient, stable MPR-based CDS construction by considering the energy and velocity of the nodes. Also, they implemented the route discovery process of AODV using CDS nodes. A node which has more energy and low velocity is selected as a dominating node. Each node in the network selects its 1-hop neighbor as a Multi Point Relay (MPR). A node in the CDS consumes more energy and its energy depletes more quickly than that of non dominating nodes.

Vijayakumar & Poongkuzhali (13) introduced the Efficient Power Aware Broadcasts (EPAB), which is expected to establish an optimal path with suitable bandwidth and battery capacity. The node rebroadcasts a message if it is received for the first time, according to high probability, ie the number of neighbors of node X is less than the average number of neighbors typical of its surrounding environment. Larry & Natarajan (14) proposed a weighted-Density Connected Dominating Set (wDCDS) based data gathering algorithm for wireless sensor networks. The wDCDS is constructed using the weighted-density of a sensor node, which is defined as the product of the number of neighbors available for the node and the fraction of the initially supplied energy available for the node. The Connected Dominating Set techniques have been discussed. The stable CDS has recently been discussed by many researchers and hence this research focuses on the stable CDS which combines signal strength and velocity. Enhancements in the CDS are proposed in this research.

3. THE PROPOSED ALGORITHM

An algorithm is proposed for Stable CDS construction based on displacement and radio signal strength. It is assumed that each node has the same antenna and power level to deliver the radio signal and also has the same transmission range R.

3.1. Route Discovery -Construction of SCDS

The functioning of the proposed algorithm has three stages. In the first stage, the dominating set is determined by identifying the highest weight value of the node, and iteratively to discover the highest cover nodes. The second stage connects the dominating set. The third stage forms the Connected Dominating Set.

Stage 1: Construction of the Dominating Set

The following steps are performed to construct the dominating set.

Step 1. Initially each node is assigned a white color.

Step 2. The node i with the highest weight value is taken as the dominator node and colored black.

Step 3. All the neighbor nodes of the node i are assigned the color brown.

Step 4. Repeat steps 2 to 4 until all the nodes in the graph G(V,E) are colored either as black or brown.

The weight value is calculated based on the rate of change of displacement and the received signal strength.

Received Signal Strength (RSS**):** RSS value is calculated with the help of two ray ground reflection model. Two ray ground reflection model is used to predict the received signal power of each node. Each node keeps a record of the received signal strength of the neighboring nodes. When a node receives a packet from a neighbor, it measures the received signal strength, P_r given in Equation 1.1.

$$P_r = P_t * Gt * G_r * h_t^2 * hr^2 / d^4 * L \qquad (1.1)$$

where P_t is the transmitted signal power; $G_t$and $G_r$are the antenna gains of the tramsitter and the receiver, h_t and hr are transmitter and receiver antenna height respectively; d is the distance.

The node receives its signal strength from the MAC layer. This information helps to decide whether a current node is placed in a high or low signal strength area. After computing the RSS, the node broadcasts this information to its 1-hop neighbors, by ‘hello’ packets. The received signal strength measured at the arrival of every packet to estimate the distance from one node to its neighbor node. The stronger the received signal strength, the closer the neighbor node. These hello packets will also help to update all the node’s RSS in the Routing Table. The RSS values are always indirectly proportional to the transmission distance (a weak RSS can cover the maximum transmission distance). For example, transmission range of node A and its neighbors are given in Figure 1

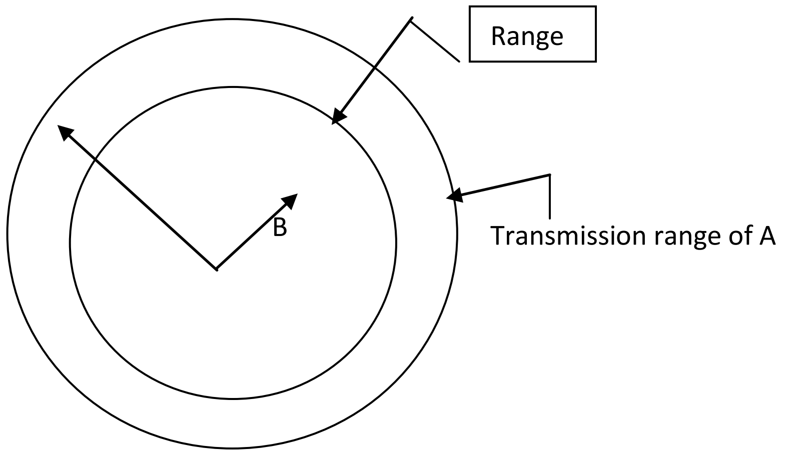


Figure 1 Node A and its neighbors

Rate of change of displacement calculation**:** Each node sends its current position and velocity information to all its neighboring nodes with the help of “hello packets” after a fixed duration T (Beacon interval). Then, it calculates the predicted new distance from its neighbors after the end of the beacon interval, based on the current velocities of the neighbors. It then checks whether the probability of the predicted distance along any axis exceeds a predefined threshold distance, R_{th1}. If the probability of the predicted distance remains greater than zero and less than R_{th1}, then that node will be considered for the dominating set.

For a particular node, say A, its neighbor is either in front of it (say B) or behind it (say C). Let V_A and V_B be the current velocity of nodes A and B. The current distance between the nodes A and B is calculated, as given in Equation 1.2.

$$d_{AB} = d_A - d_B \qquad (1.2)$$

R_{th1} and R_{th2} are the threshold distance, and the value is assumed, based on the maximum range of communication, ie, $R_{th1} < R_{max}/V2 - X$ and $R_{th2} < R_{th1} + X$, where V2 is the average velocity of the nodes A and B, and X is the transmission range minus 20. Let T be the beacon interval, the new distance between the nodes A and B is calculated after time T, as given in Equation 1.3.

$$d_{AB}(new) = d_{AB} + [V_B - V_A] \text{ x } T \qquad (1.3)$$

if $d_{AB}(new) < 0$ or if $d_{AB}(new) > R_{th1}$ the distance between A and B is not a stable distance.

Unfavorable Communication Range: If $d_{AB}(new)<0$ or $d_{AB}(new) > R_{th1}$, the nodes do not come under the safe region; it is not in the good communication range. The nodes A and B move very fast and out of the communication range. Hence, it is considered as an unfavorable communication range.

Favorable Communication Range: If $d_{AB}(new)<0$ or $d_{AB}(new) > R_{th1}$,the nodes are in the good communication range. The nodes A and B move in such a way that they do not move out of the communication range. They are inside the communication range after a beacon time interval T. Hence, it is considered as a favorable communication range.

Medium communication Range: If $d_{AB}(new) > R_{th1}$ and $d_{AB}(new) < R_{th2}$, the nodes in the medium communication range. The nodes move in the boundary region, and it is considered as a medium communication range.

SCDS uses the following fields with each route table entry:

- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence Number flag
- Other state and routing flags (e.g., valid, invalid, reparable, being repaired)
- Network Interface
- Hop Count (number of hops needed to reach destination)
- Next Hop
- List of Precursors
- Lifetime (expiration or deletion time of the route)

In the routing table, one more field for the weight is included to store the weight value of the node. The flow chart for the Dominating Set Construction is shown in Figure 2

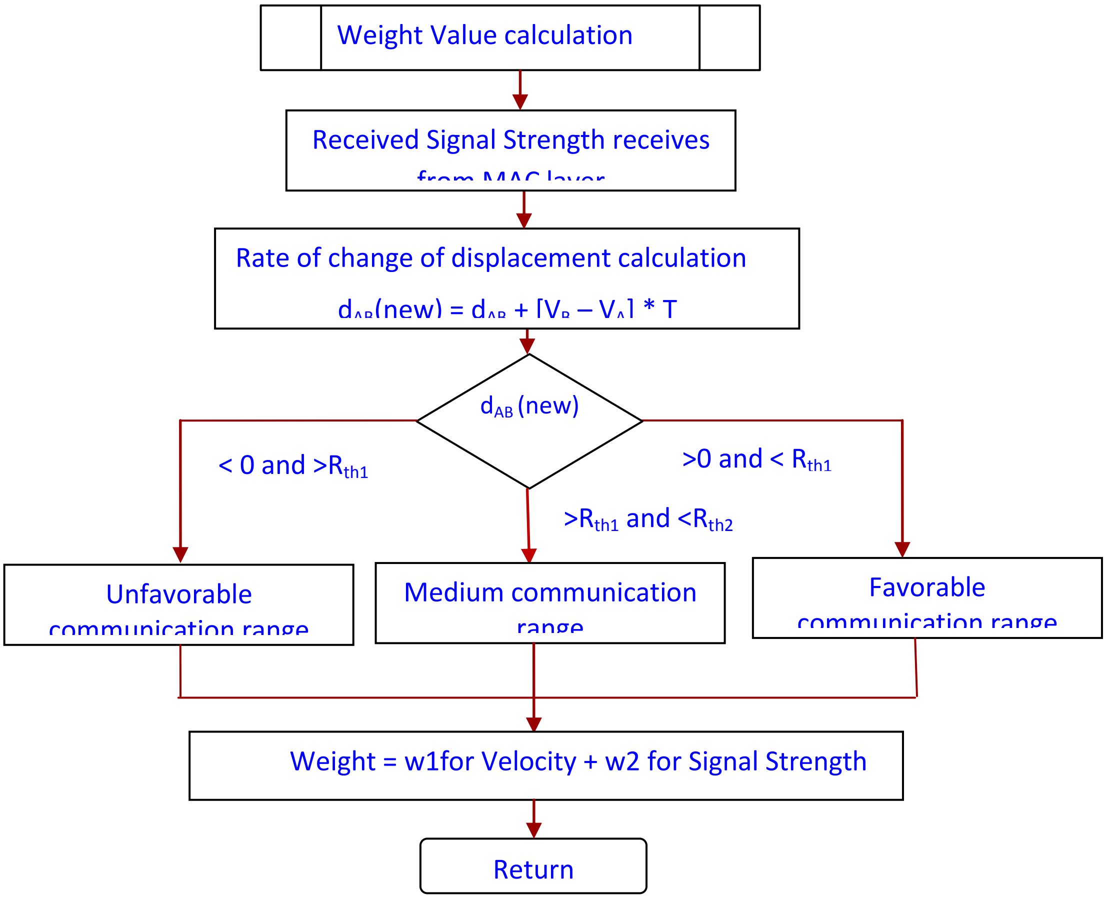


Figure 2 Dominating Set Construction

3.2. *Connected Dominating Set Formation*

In this stage a set of connectors, C, is found, such that all the nodes in the dominating set, D, get connected. The following steps are used for the CDS formation.

1. A node that is connected to the maximum (k) number of green nodes is selected; it is assigned a blue color.
2. It is checked whether there exists a node, that is connected to the adjacent green nodes in the dominating set, D.
3. If D gets connected, the process is concluded. Else we go to step 1 with k–1 number of green nodes.

In this stage, the cardinality of the CDS set may be tried to reduce. This involves the following steps.

1. Let F= Set of CDS members. While the set CDS is not empty, perform the following steps.
2. A node u which is having minimum degree is selected from the CDS graph.
3. It is checked whether N[u] is a subset of N[1], N[2],....,N[n] where N[u] is the neighbors of node u and N[1], N[2]...N[i] where i belongs to F-{u} and N[i] is the neighbors node of i.
4. If step 2 returns true, then node u is removed ie F=F-{u}. Otherwise the node u is not removed.

LetF={v_1,v_2,.....v_n}bea CDS of graph G.Without the loss of generality, it is assume that $deg_G(v_1) \leq deg_G(v_2) \leq$ ....$\leq deg_G(v_n)$.

If $N_G[v_1]$ € Ui=2 ..n N[v_i], then consider F=F-{v_1} Otherwise consider the same set F.Continuing this process for the vertices v_2,v_3.....v_{i-1}.

Now if N[v_i]€Uj=i+1..n N[v_j], then consider F=F-{v_i} Otherwise consider the same set F.

The same process will repeat for the vertices v_{i+1},v_{i+2}....v_n.

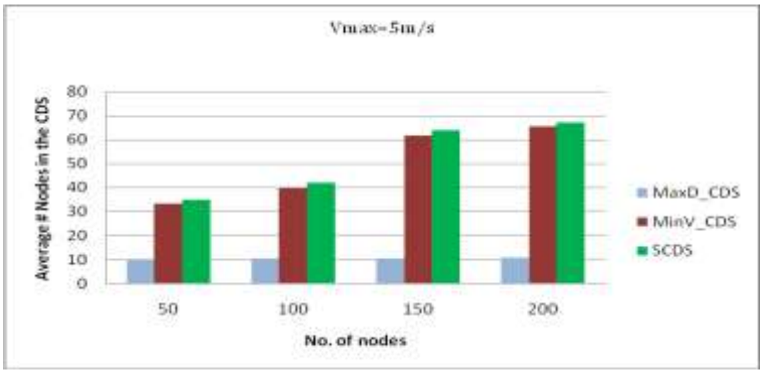
It is clear that for each step, the cardinality of set generating the CDS set is less than or equal to the cardinality of the set generating in the previous step. Finally we obtained a CDS set.

Select the minimum degree node of the connected dominating set and check whether its neighbour nodes are in the subset of the connected dominating set. If it is in the CDS, then that node is not considered in the next stage.

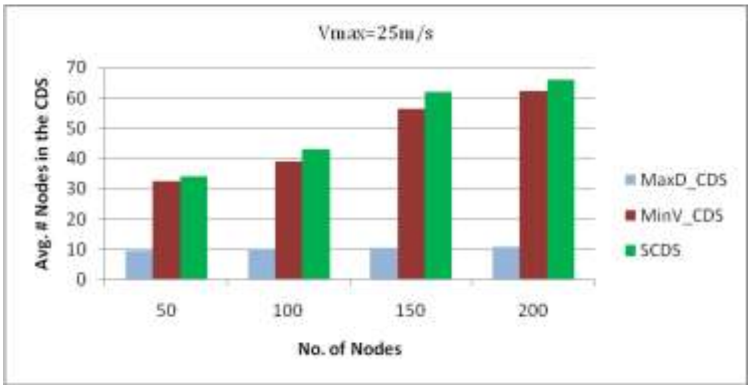
4. SIMULATION AND PERFORMANCE ANALYSIS

The performance of the proposed method is evaluated, in terms of CDS node size, CDS life time and hop count per path. The NS2 simulation results of the SCDS system are reported and analyzed.The performance of the proposed SCDS in terms of CDS Node Size, CDS Life Time and Hop count per path are obtained, and compared with that of the MaxD_CDS (19) and MinV_CDS (20).

4.1 CDS Node Size



(a) V_{max} = 5 m/s



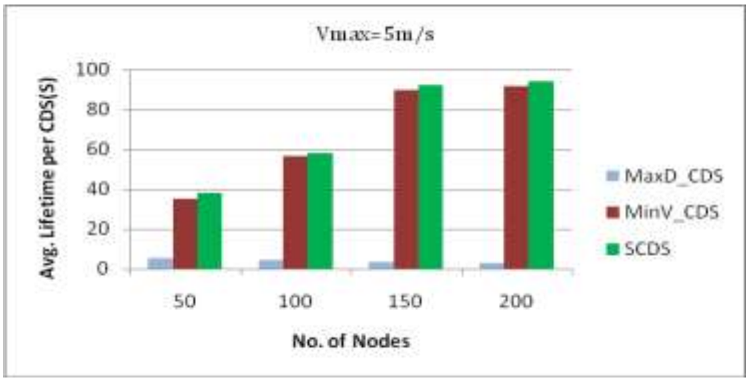
(b) V_{max} = 25 m/s

Figure 3 (a & b) CDS node size: Average number of nodes in MaxD_CDS, MinV_CDS and SCDS

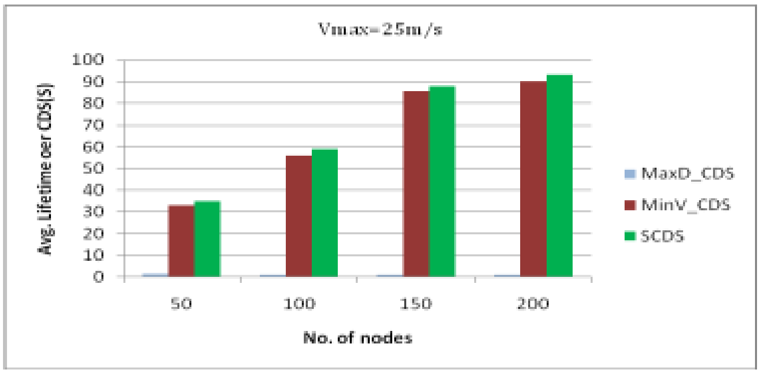
Figure 3, The CDS Node Size is the time-averaged value of the number of nodes that are part of the CDS, calculated using the MaxD_CDS, MinV_CDS and SCDS algorithms. The MaxD_CDS algorithm is fully density-based, and is expected to minimize the number of constituent nodes of the CDS as it gives preference to nodes that have a larger number of uncovered neighbors over nodes that have a smaller number of uncovered neighbors. But, the stable CDS (SCDS) does not give much importance to the number of uncovered neighbors of a node before including the node in Node list of CDS. If a node has a highest weight value and is the next candidate node to be considered for inclusion in the list of CDS, the lowest weight value of a node is added to the node list of CDS if it has at least one neighbor that is yet to be covered. As a result, the number of nodes in the node list of CDS is relatively high for the CDS based on velocity and signal strength. A long-living stable CDS is eventually formed by including more nodes to the part of the CDS. While, even if the network density is double, the MaxD_CDS algorithms tries to cover all the nodes in the high-density network by incurring only a few percentage increase in the CDS node size, compared to that for a low density network. In a given node density, if the node mobility increases from low to high, the Node Size for a MaxD_CDS does not change appreciably, whereas the Node Size for a SCDS changes appreciably (Figure 3 a,b). When the numbers of nodes are less, the average number of nodes in the CDS of SCDS is 5.42% greater than the average number of nodes in CDS of MinV_CDS in the speed 5m/s. When the numbers of nodes are high, the average number of nodes in the CDS of SCDS is 2.45% greater than the average number of nodes in the CDS of MinV_CDS in the speed 5m/s. When the numbers of nodes are less, the average number of nodes in the CDS of SCDS is 4.29% greater than the average number of nodes in CDS of MinV_CDS in the speed 25m/s. When the numbers of nodes are high, the average number of nodes in the CDS of SCDS is 5.77% greater than the average number of nodes in the CDS of MinV_CDS in the speed 25m/s. The reason is that the distance between the two nodes is less or greater after a time t is calculated using the velocity of the two nodes and based on that the nodes are selected in the proposed SCDS algorithm. The greater number of nodes in CDS size will give the long average life time.

4.2 CDS Life Time

The CDS Life Time is the time that elapsed between the discovery of a CDS and its disconnection, averaged over the entire duration of the simulation. From Figure 4 (a,b), it is understood that the effective lifetime of the SCDS is always significantly larger than that of MaxD_CDS, especially with an increase in the network density as well as node mobility. In the case of MinV_CDS and SCDS, the relatively large CDS node size greatly contributes to the life time of the CDS. As the constitutent nodes of SCDS are selected based on the rate of change of displacement and signal strength, the edges between the CDS nodes are bound to exist for a relatively longer time and the connectivity of the nodes that are part of the SCDS is likely to be maintained for a longer time. But the MaxD_CDS algorithm chooses nodes that are far away from each other as part of the CDS. The edges between such nodes are likely to fail sooner, leading to loss of connectivity between the nodes that are part of the MaxD_CDS.



(a) V_{max} = 5 m/s

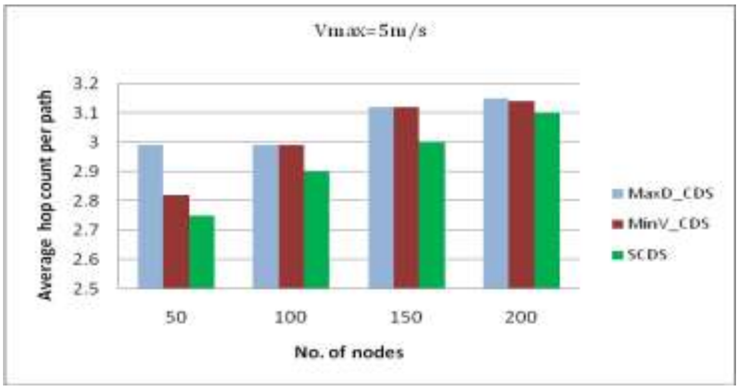


(b) V_{max} = 25 m/s

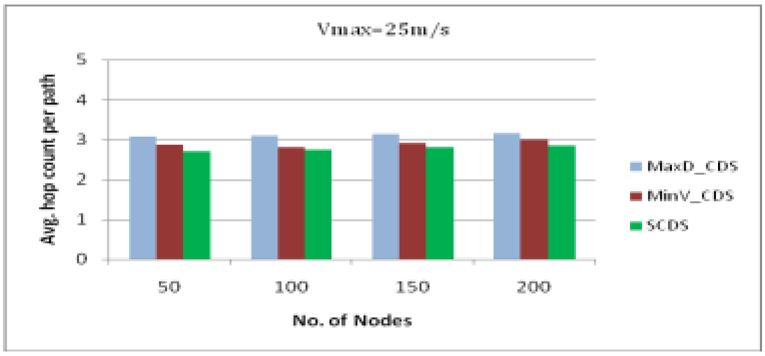
Figure 4 (a & b) Average lifetime for MaxD_CDS, MinV_CDS and SCDS

The algorithm MinV_CDS also chooses the nodes that are having low velocity, present near the boundary and move away from the boundary sooner, leading to link failure between the nodes that are part of the MinV_CDS. The distance between two nodes are calculated after a time t is using the velocity of the nodes and the nodes are to be part of the CDS is choosen if they are moving towards each other, the lifetime of the CDS could be significantly improved, at the expense of the node Size. But, if we select a CDS with the minimum number of nodes required to cover all the nodes in the network, the lifetime of the CDS would be significantly lower. The lifetime of SCDS is 8.57% greater than MinV_CDS at the speed of 5m/s when the number of nodes is less. But when the number of nodes increases, the lifetime of SCDS is only 2.73% greater than MinV_CDS at the speed of 5m/s. When the speed is increased to 25m/s, the lifetime of SCDS is 6.06% greater than MinV_CDS when the number of nodes is less.

4.3 Hop Count Per Path



(a) V_{max} = 5 m/s



(b) V_{max} = 25 m/s

Figure 5 (a & b) Hop count per path through CDS nodes for MaxD_CDS, MinV_CDS and SCDS

The hop count per path is the time-averaged hop count of the individual source–destination (s-d) paths involving the CDS nodes, as the source, intermediate and destination nodes, averaged across all the s-d paths over the entire simulation period. The relatively lower hop count per s-d path, in the case of a SCDS, can be attributed to the larger CDS Node Size and the presence of a larger number of edges connecting the CDS nodes. Hence, the SCDS have several s-d paths between any two nodes s and d in the network and minimum hop s-d path among them is chosen while computing the average hop count per path (Figure 5 a,b). On the other hand, with fewer edges in the MaxD_CDS, the paths between any two nodes through the nodes of the MaxD_CDS will have a relatively larger hop count. In MaxD_CDS, the fewer number of nodes in CDS with larger hop count per path gives larger end-to-end delay per data packet and unfairness of node usage. The SCDS, as multiple nodes are part of the CDS, the packet forwarding load can be distributed across several nodes and this could enhance the fairness of node usage and help to incur a relatively lower end-to-end delay per data packent. The average hop count in SCDS is reduced by 2.48% and 1.27% respectively in the no. of nodes are less and high compared to MinV_CDS at the speed of 5m/s. In the high speed of 25m/s, the average hop count in SCDS is considerably reduced by 5.59% and 5% respectively in the no. of nodes are less and high compared to MinV_CDS. The reason is that the number of nodes in CDS Node Size is high in the high speed and there are more possible to find the shorter path and hence the average hop count is also less in the high speed.

5. CONCLUSION

In this study, a new algorithm is proposed based on the rate of change of displacement and signal strength. The NS2 implementation of the AODV routing protocol has been modified to incorporate the new route discovery mechanism. Numerous simulation runs have been conducted on the SCDS, and the performance results have been compared against those of the traditional MaxD_CDS and MinV_CDS. The performance analysis has been conducted under different network operating conditions. Firstly, the impact of the CDS Node size on the performance of the routing protocols is assessed, by varying the number of nodes in the fixed topology area. Secondly, the performance analysis of the routing protocols has been conducted under the CDS Life time. Finally, it is analyzed by the Hop count per path through CDS nodes. Through simulations, it is demonstrated that the proposed algorithm, SCDS, can find the connected dominating sets that have a significantly longer life time compared to that of MaxD_CDS algorithm. The SCDS has a relatively larger number of constituent nodes and this helps to reduce the hop count per path. SCDS chooses the node which is the neighbor coming closer to it after a time t using the velocity of the nodes to be part of the CDS, hence the lifetime of the CDS could be significantly improved, at the expense of Node size.

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