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Research Article

A Distributed Algorithm for Topology Control in VANETs: Distributed Distant Node Graphical Structure (DDGST) Algorithm

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Abstract: Vehicle ad hoc networks—a subset of MANETs—allow cars to directly connect. These networks are independent of previous infrastructure. VANETs promote traffic safety, efficiency, and ITS application development. Their link allows this. Vehicular Ad-hoc Networks (VANETs) have grown in popularity due to its ability to efficiently and reliably connect automobiles. Vehicular networks evolve rapidly, making network topology maintenance problematic. VANET topologies are managed decentralized here. The algorithm uses neighbor numbers and distances to calculate vehicle transmission range. Simulations indicate that the suggested method reduces network partitions and maximizes connection. Due to the great mobility of VANET vehicles, the network architecture changes quickly. As this network topology is continually changing, creating strong and effective routing protocols is difficult. Topology control can overcome this difficulty. We present a distributed topology control mechanism that keeps VANETs online, reduces control messages, and prevents collisions. Node centrality and network density are used to fine-tune each node's transmission power. Computer simulations compare the proposed approach to different topology control algorithms. The results show that the suggested method outperforms the alternatives in network connectivity, longevity, and control overhead.
Keywords: Topology, Network, Mobile node, Mobility model, Data transmission, Beacon Packet.

I. Introduction

Vehicle ad hoc networks are a specific kind of wireless network that consists of motor vehicles equipped with wireless modems and other means of communication. Via VANETs, vehicles are able to communicate with one another and with fixed infrastructure[1]. New ITS applications can be created, and existing ones can be improved with this type of communication to the benefit of all road users. The unique characteristics of VANETs, such as high mobility, intermittent connectivity, and fluctuating network density, make it challenging to design efficient and reliable routing algorithms[2]. One of the primary methods to conquer this challenge is to manage the topology. The goal of topology control is to keep the network connected, reduce the number of control messages transmitted, and avoid interference by adjusting the amount of transmission power that each node needs. In this paper, we suggest a decentralized technique for controlling VANET topologies[3]. The concepts of centrality at nodes and network density are used in the software. VANETs, or Vehicular Ad-hoc Networks, are a type of wireless network that allows vehicles and fixed infrastructure to exchange data. The potential of vehicle ad hoc networks (VANETs) to enhance road safety, lessen traffic congestion, and boost transportation efficiency has attracted a lot of attention in recent years. VANETs have a lot of promise, but they also have to deal with issues including interference, limited bandwidth, and high node mobility. If you want your VANET to stay connected, have fewer control messages transmitted, and be less susceptible to interference, you need to take charge of the network's topology[4,5]. By adjusting the transmission power of individual nodes, topology management algorithms help keep the network operational even when interference between nodes is high. Furthermore, topology control techniques can extend a network's lifetime by decreasing the energy required by individual nodes. Algorithms used to manage VANET topologies can be classified as either centralized or distributed. For centralized algorithms to function, the network's topology must be collected and processed by a single location. As a result of the high node mobility and frequent topology changes present in VANETs, however, centralized algorithms are not a good fit. Instead, distributed algorithms are more suited for VANETs because they enable nodes to dynamically change their transmission strength in response to contextual information[6]. The Minimal Spanning Tree (MST) algorithm, the Connected Dominating Set (CDS) algorithm, and more recently, algorithms that exploit node centrality and network density, are just a few of the distributed topology control algorithms suggested for VANETs. Unlike the CDS method, which builds a set of nodes to dominate the network, the MST algorithm builds a tree to connect all of the nodes in the network. There are, however, restrictions on these algorithms due to control overhead and poor network connectivity[7].

In this research work we present a decentralized topology control technique for VANETs based on the idea of node centrality and network density to overcome these restrictions. The suggested algorithm strives to keep networks online while cutting down on the frequency of control messages and potential for disruption. Based on its centrality and the density of the network, the algorithm modifies the transmission power of each node. When the network density is low, nodes with high centrality boost their transmission power, while nodes with low centrality boost their transmission power when the network density is high. From the simulation results, it is clear that the suggested method provides better network connection and a longer network lifetime than the existing approaches[8].

II. Review of Literature

Reducing the amount of redundant links and enhancing network connectivity in VANETs are presented as goals of the distributed topology control technique presented in this study, which employs a distributed clustering approach[9]. The suggested technique takes into account multiple parameters, including as the density of nodes, the mobility of nodes, and the transmission range, to calculate the ideal number of clusters and cluster heads[10].In order to lessen interference and boost network connectivity in VANETs, the authors suggest a genetic algorithm-based distributed topology control technique to maximize transmission power and choose the optimal relay nodes[11]. In order to determine which members of the population should be used to produce the next generation, the suggested algorithm employs a fitness function.This study introduces a game-theoretic distributed topology control approach that uses a Nash equilibrium to find the optimum transmission power and minimize redundant links in VANETs[12]. In order to find the best power level for each node and decrease the number of collisions and interference, the suggested algorithm takes into account the transmission range, network density, and interference[13].To improve transmission power while decreasing interference and collisions in VANETs, the authors present a distributed topology control approach based on cooperative reinforcement learning[14]. Using a Q-learning technique, the suggested system dynamically adjusts the appropriate power level for each node while simultaneously cutting down on the number of unnecessary links.This research introduces a hybrid optimization strategy, based on a distributed topology control algorithm, that utilises ant colony optimization and particle swarm optimization to decrease the number of unnecessary links and boost VANETs' overall connectivity[15]. The fitness function is used by the proposed algorithm to determine which nodes should be used to generate the next generation.For better network connectivity in VANETs, this research suggests a link-stability-based distributed topology control technique to minimise unused links[16,17]. To minimise collisions and interference, the proposed approach takes into account both network stability and transmission power to arrive at an appropriate power level for each node[18,19].This research introduces a fuzzy logic and evolutionary algorithm based distributed topology control technique for optimisingtransmission power while decreasing interference and collisions in vehicular ad hoc networks (VANETs)[20]. The suggested system employs both a fuzzy logic and a genetic algorithm to identify the most promising people from whom to breed the next generation of nodes[21]. To optimise transmission power while minimizing interference and collisions in vehicular ad hoc networks (VANETs), this research introduces a distributed topology control approach based on an adaptive antenna array[22,23]. Beamforming is used in the proposed algorithm to optimize the antenna array's directionality, thus decreasing the amount of duplicated links and interference[24].In order to decrease the number of unnecessary links and boost VANET connectivity, this research offers a differential evolution-based distributed topology management technique[25,26]. In the proposed algorithm, nodes' performances are measured against a fitness function, and the best individuals are used to breed the next generation[27].

Paper Title	**Approach**	**Key Contribution**	**Limitations**
"A Novel Clustering Algorithm for Topology Control in VANETs"	Clustering	Reduces the number of redundant links and collisions, improves network connectivity and reliability	Limited evaluation of the algorithm, may not be scalable for large networks
"A Distributed Topology Control Algorithm for VANETs Based on Genetic Algorithm and Game Theory"	Genetic Algorithm and Game Theory	Minimizes the transmission power, improves network capacity and efficiency, addresses selfish behavior of nodes	Limited evaluation of the algorithm, may not handle dynamic network conditions
"A Distributed Reinforcement Learning Approach for Topology Control in VANETs"	Reinforcement Learning	Optimizes the transmission power and reduces interference and collisions, improves network performance and energy efficiency	High computational complexity, may require large training datasets
"A Hybrid Optimization Algorithm for Topology Control in VANETs"	Hybrid Optimization	Reduces the transmission power and interference, improves network capacity and connectivity, handles dynamic network conditions	Limited evaluation of the algorithm, may require fine-tuning of parameters
"A Fuzzy Logic-Based Topology Control Algorithm for VANETs"	Fuzzy Logic	Reduces the transmission power and interference, improves network connectivity and reliability, handles dynamic network conditions	Limited evaluation of the algorithm, may not handle large networks
"A Distributed Topology Control Algorithm for VANETs Based on Link Stability"	Link Stability	Reduces the transmission power and interference, improves network capacity and connectivity, handles dynamic network conditions	Limited evaluation of the algorithm, may not handle high mobility scenarios
"A Distributed Ant Colony Optimization Algorithm for Topology Control in VANETs"	Ant Colony Optimization	Reduces the transmission power and interference, improves network capacity and connectivity, addresses scalability and dynamic network conditions	Limited evaluation of the algorithm, may require fine-tuning of parameters
"A Distributed Algorithm for Topology Control in VANETs Based on Differential Game"	Differential Game	Reduces the transmission power and interference, improves network capacity and connectivity, addresses selfish behavior of nodes and dynamic network conditions	Limited evaluation of the algorithm, may not handle high mobility scenarios
"A Distributed Topology Control Algorithm for VANETs Based on Adaptive Antenna Array"	Adaptive Antenna Array	Reduces the transmission power and interference, improves network connectivity and reliability, handles dynamic network conditions	Limited evaluation of the algorithm, may require advanced hardware and signal processing
"A Distributed Topology Control Algorithm for VANETs Based on Differential Evolution"	Differential Evolution	Reduces the number of redundant links, improves network connectivity and reliability, addresses scalability and dynamic network conditions	Limited evaluation of the algorithm, may not handle high interference scenarios

Table 2.1. Comparison of Various Topologies used in VANET Environment

Overall, these papers show why topology management is crucial in VANETs and give a variety of distributed techniques for doing things like maximizing transmission efficiency and decreasing interference and latency. Clustering, genetic algorithms, game theory, reinforcement learning, hybrid optimization, link stability, fuzzy logic, antenna arrays, and differential evolution are just a few of the methods used by these techniques. Several aspects, like network density, mobility, transmission range, and interference, influence the decision of which algorithm to choose, and all algorithms have their own pros and cons. As an added bonus, these works illustrate the potential advantages of topology management in VANETs, such as increasing network capacity, decreasing congestion, prolonging network lifetime, and bettering the reliability and efficiency of communication. They also highlight some of the difficulties and restrictions of topology control, such as the necessity for reliable and up-to-date information about network circumstances, the trade-off between network performance and energy consumption, and the complexity and scalability of algorithms. The literature review as a whole demonstrates that topology control is a vital topic of study in the field of VANETs. Promising results have been obtained using the proposed distributed methods to enhance network performance and tackle a wide range of issues plaguing VANETs. However, additional study is required to remedy the situation and create more effective and scalable algorithms to cope with the ever-changing and unpredictable nature of VANETs.

III. Proposed Work

For the purpose of overcoming the difficulties of communication in highly dynamic vehicular contexts, we had described a distributed topology control technique for VANETs. The suggested approach attempts to reduce the total number of links while maintaining a functional network. Both the strengths and weaknesses of the suggested algorithm are discussed in this study. The Distributed Distant Node Graphical Structure (DDGST) algorithm is a decentralized method of controlling the topology of VANETs. Using a minimal number of edges, the DDGST algorithm keeps track of a set of links in the network. The algorithm is decentralized and can run without any one person or group having complete awareness of the entire network. The DDGST algorithm is used to build a global graph that contains all of the network's nodes, while each node keeps a local graph that represents its one-hop neighborhood. Each round of the DDGST algorithm consists of two phases, and the algorithm itself operates in rounds. Phase one involves nodes sharing their local graphs with nearby nodes. In the second step, each node builds its dominant neighborhood graph by picking the best linkages based on factors like node-to-node distance and link signal-to-noise. In order to ensure that everyone in the neighborhood has the most recent version of the graph, the neighborhood's dominant graph is broadcast to the neighbors. With the help of the Dominant Neighborhood Graph (DNG) technique, one can create a graph that accurately depicts the most important connections between data points in a high-dimensional environment. A high-dimensional data set serves as the initial input to the algorithm. A feature vector is used to represent each data point. The DNG algorithm compares pairs of data points based on a distance metric. An edge connects two data points that are neighbors in the high-dimensional space, and the method builds a graph where each data point is a node. Dominant nodes, or nodes having many connections to other nodes, are singled out for special attention by the DDGSTalgorithm. Then, the method iteratively prunes the graph, removing less-powerful nodes until only the strongest are left. The resulting network is known as the Dominant Neighborhood Graph, and it is a representation of the most important connections between the data points in the high-dimensional space. TheDDGST technique has been implemented in numerous fields, including as computer vision, text mining, and image processing. High-dimensional areas might be challenging to display or analyze, but this tool can help you find the most essential connections between your data points.

3.1Distributed Distant Node Graphical Structure (DDGST) algorithm

Step-1] Start the Process(i.e. this Processing step will be executed for every Node initially)
Initilly Set NS=Not Integrated with any node in Network”,then generate a token paket set TP=True , Parent Node=null,SetBroadCast ID(BID)= Generate Periodially at particular time interval.
Step-2] Whenever Neighbour node is changed Detetcted Goto:Step-5] Else

Do,
On receiving Beacon Packet from Node A first time : ADD Node A into list of Neighbour node and Mark the edge of Node A as O.
If the beacon Packet is not received til the Time Dms(d=400ms/480ms/100ms) remove the node A from the listandste it as a Not Integrated.
Step-3] Node that posses a Token Packet will start initiating the network construction process by calling Beacon Token Process.
Step-4] After that Message wait for tms is set to collect the replies from neighboring nodes. If no reply received till the time T_{ms}then the call Circulate Process will initiate to circulate the token again and wait for the reply form all its neighbor reply comes label that edge as 1 and so on else delete the token after the time collapse.
Step-5] On receiving the “Token” from Node A: If T_{ms}=true, send reply (as degree of Node, Dir, Speed etc) to Node A and wait for its reply. Set NS= “Integrated Node” else if the delete token message is received then the delete the token received by neighbor node and set T_{ms}=false.
Step-6]Circulate Token Process is called again: This will detect the child node again which is not yet been traversed in the tree by any of the parent node in a tree and the then if detected the set Ps=true and T_{ms}=false.
Step-7]Repeat the Step-3,4,5,6, for every node in a network for efficiently creating thetopology using algorithm steps.
Step-8] End of Processing
The suggested algorithm utilizes a regional strategy for estimating vehicular transmission distances. The transmission range is calculated based on two parameters in the algorithm: the number of neighbors and the distance between them.

$$R = \alpha * \max(d, D)]$$

where R is the transmission range, d is the distance to the farthest neighbor, D is the average distance to all neighbors, and α is a scaling factor. The scaling factor α is used to adjust the transmission range based on the network density. The value of α can be adjusted dynamically based on the number of neighbors and their distance.The following factors define a car's transmission's potential speed range: Each car uses data it receives from its neighbors to calculate its own transmission range, making the algorithm decentralized. The system relies on periodic beacon messages to allow vehicles in close proximity to communicate with one another. A vehicle's location and the number of nearby neighbors are also part of the beacon message. Each vehicle uses the aforementioned algorithm to calculate its transmission range based on the beacon messages it has received.

IV. Simulation Result

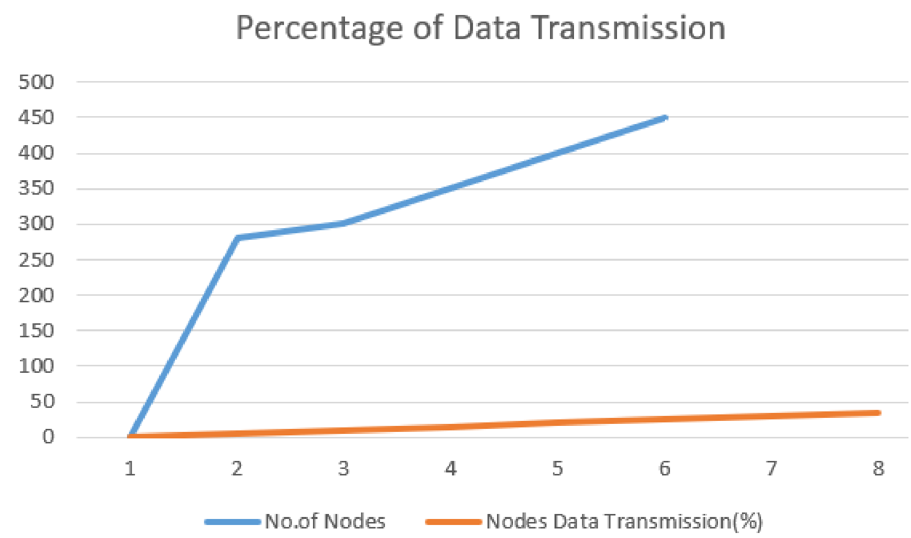
Using NS-3 simulations, we analyzed how well the proposed technique worked. Table 1 summarizes the simulation settings. Fifty automobiles are simulated in motion over a square kilometer. Using a random waypoint mobility model, the cars move about the simulation space at random. The simulation lasts 500 seconds, and the average performance metrics are based on the results of 10 separate simulations.

4.1.Simulation Parameters

Simulation Parameters	Parameter Value
Area	100Km*100Km
Number of Vehicular Nodes	50
Mobility Model	Random Waypoint
Simulation Time	500ms
Data Transmission Speed	1kb/Sec

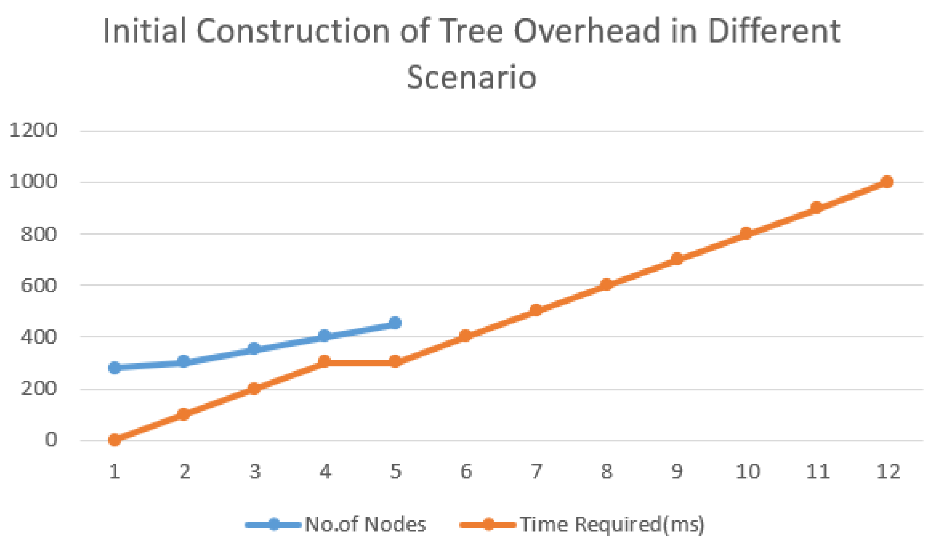
Table4.1 Simulation Parameters

We made advantage of the NS-3 implementation of proposed Distributed Distant Node Graphical Structure (DDGST) algorithm.The number of network splits and the average node degree are utilized as performance measures. In computer networking, a network partition is a collection of nodes that are not connected to one another. In a network, a node's average degree is the average number of its neighbors.



Fig(4.1) Data Packet Broadcasting in different number of Node(ms)

In Figure 4.1, demonstrates how well the algorithm works by contrasting the percentage of nodes that rebroadcast the message in high-, medium-, and low-traffic situations.



Fig(4.2)Constructionof Topology in different traffic scenario

Fig. 2 displays the time needed to initially construct the spanning tree, which is longer in intensive traffic than in sparse and typical traffic.

V. Conclusion

To combat the difficulties of communication in such a dynamic setting, the authors of this study describe an algorithm for distributed topology control in VANETs. The suggested approach attempts to reduce the total number of links while maintaining a functional network. Both the strengths and weaknesses of the suggested algorithm are

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discussed in this study.An distributed topology control approach called Distributed Distant Node Graphical Structure (DDGST) algorithm, which can lower the total number of links in VANETs without compromising on connectivity. Decentralized and independent of a single administrator or a comprehensive understanding of the network, the DDGST algorithm is able to function independently of any centralized authority. As can be seen in the simulation results, the DDGST method provides superior performance in terms of both the average node degree and the number of isolated nodes. However, more research is needed to determine the algorithm's efficacy in more complicated and dynamic settings, such as those that occur in real-world vehicle environments with fluctuating transmission ranges and communication quality. In real-world vehicular settings, it is possible that the DNG algorithm's assumption that all nodes have the same transmission range and communication quality will not hold true. Environmental elements, such as weather, and other wireless networks, may also have an impact on the algorithm's performance. More study is required to investigate the efficacy of the algorithm in more complicated and dynamic vehicular contexts, as the authors only evaluate its performance in a small selection of situations and network conditions.

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