Detecting and Controlling the Occurrence of Data Congestion in a High-density VANETs Environment

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***Abstract*—Vehicular Ad-hoc NETworks (VANETs) is a specialized kind of Mobile Ad-hoc Network (MANETs) class as it works with the safety of vehicles that are moving on the roads. There are several difficulties, and data congestion is a leading hurdle. This paper starts with generating an appropriate route that will be employed to identify data congestion in a high-density VANETs environment. Next, a suitable approach is introduced for controlling and managing that detected data congestion. Subsequently, the network's performance after introducing our proposed approach is analyzed by considering three distinct parameters, including Packet Loss Ratio (PLR), Delay, and Throughput. These metrics are applied to investigate the performance of four different algorithms: CABS, UO-Tabu, MO-Tabu, and VANETomo, along with our proposed algorithm. The comparison outcomes declared that our recommended algorithm provides more reliable results than the other algorithms. Our suggested algorithm provides the immense value for the Throughput and the least value for the PLR and Average Delay. This paper is concluded by projecting to select additional novel metrics and strategies to detect and manage the data congestion occurring in VANETs.**

I. Introduction

VANETs is a group of MANETs that intends to employ wireless technologies in the Intelligent Transport Systems (ITSs) [1]. VANETs have many special features, for example, high node movement, high density of nodes, a huge change in topology, and many more. These special features also give rise to many hurdles and difficulties in scheduling and transferring the data in the field of VANETs [2]. When the vehicles are continuously sending messages to their nearby vehicles in highly dense conditions, the shared channels are most likely to be congested with a large volume of worthless messages [3]. The occurrence of congestion in return leads to the rise in packet-loss and delay, simultaneously declines the VANETS network's execution. Hence, congestion must be managed for improving the dependability of VANETs [4], [5]. Approaches for controlling the congestion aims at managing the load assigned to the channels and give fair channel access between the vehicles. In the field of VANETs, the traffic circumstances constantly change among alternately scattered and dense situations. As a result, rising in dynamic, irregular, and extremely portable vehicular nodes also diminishing the application performance [6]. To address data congestion problems in VANETs, several strategies for controlling the congestion have been proposed. In these strategies, various techniques have been utilized for the goal of identifying and controlling the congestion.

Congestion occurring in the network due to the transmitting data is termed as *Data Congestion*. This type of congestion in VANETs occurs because all the vehicles present in the network start their communication with neighboring vehicles simultaneously by sending several messages [7]. The network needs to handle many unnecessary messages at the same time that will cause the occurrence of congestion in the high-density VANETs environment. Data congestion in vehicular conditions degrades the Quality-of-Service (QoS) [2] [8] that indicates the congestion issue needs to be resolved soon for the proper functioning of the VANETs environment. This problem can be fixed either by increasing the capability or controlling the data packets' rate. Our research concentrates on approaches that will control the transfer of data in communication networks. Many authors recommended their approaches towards the detection and controlling of data congestion. For example, the authors in [9] suggested a method to measure the density of traffic in Vehicle-to-Vehicle (V2V) communications [10]. Methods for controlling the congestion in the wired as well as a wireless network has been well-reviewed in the research literature [11]. In MANETs, researchers concentrate on backward adaptability in multi-hop channels [12]. However, the novel hurdles and conditions of the VANETs environment indicate that these current methods will not be appropriate to be employed directly for VANETs connection. Moreover, managing the congestion in VANETs becomes extra challenging because of the high movement of nodes and channel fading restrictions.

To resolve these data congestion problems, this paper elaborates on congestion detection and control approaches employed for the field of VANETs. In this paper, we mentioned many such existing approaches that will manage data congestion in the vehicular environment. Also, we recommended a novel approach towards the detection and controlling of data congestion happening in the high-density VANETs environment. The foremost motive of this study and recommending the congestion managing approach is to manage network

TABLE I. OVERVIEW ON CONGESTION CONTROL APPROACHES

Algorithm	Message Type	Parameters Used	Control Type	Model Applied	Simulator Used
1. AIMD [13]	Beacon	Reception rate	Rate control	NA	Own simulator
2. AC3 [14]	Beacon	CBR	Power control	NA	Veins and Omnet++
3. LIMERIC [12]	Beacon	CBR	Rate control	NA	NS-2
4. MD-DCC [15]	Beacon	Channel Busy Time	Hybrid	NA	SUMO and NS-3
5. PULSAR [16]	Event-Driven	CBR	Rate Control	Reyleigh	NS-2
6. SBAPC [17]	Beacon	Beacon Error Rate and CBR	Power Control	NA	Veins and Omnet++
7. VANETomo [18]	Beacon	CBR	Hybrid	RayGround and Nakagami propagation	NS-2, SUMO and MOVE

channels when these channels are over-loaded.

The remaining paper is outlined as follows. A summary of the VANETs existing work is compiled in Section II along with the overview on the congestion control strategies. Section III highlighted our proposed work, including the approach and recommended algorithms. Section IV refines the simulation outcomes and analysis concerning the evaluation results. Lastly, the conclusion and the work to be carried out in the future are represented in Section V.

II. Related Work

The evolution of a congestion control approach bears several difficulties and challenges. The techniques used for controlling congestion in VANETs have been examined in several research studies [19]. They normally modify few transmission metrics dynamically, for example, beacon generation rate, transmission power rate, message delivery rate, and many other parameters. The authors in [20] recommended a protocol named Adaptive Traffic Beaconing (ATB). The fundamental intention is to achieve the network-load control to overcome scalability concerns of data distribution in the VANETs environment. However, this protocol does not have an idea that solves the difficulty of prioritizing messages that arise when all vehicles simultaneously broadcast the message. In [21], the researchers recommended the new protocol named Distributed-Fair Power Adjustment (D-FPAV) protocol. It manages the vehicle's transmission-power by holding the beacon-traffic beneath the highest beacon load. The broadcast range for the nodes is reduced to manage the occurrence of congestion. In [22], the authors examined the trade-off within the transmitting performance and reliability. Also, received the optimal possibility for the broadcasting of packets corresponding to the density of a vehicle. Then a strategy for controlling the congestion is introduced to obtain maximum transmitting efficiency. The authors in [23] suggested another technique for controlling the channel congestion depending upon the adoption of beacon range, transmission-rate, and a consolidation of these two mentioned parameters. They discovered that a collective rate-length congestion control technique contributed higher adaptability than techniques with individual parameters by analyzing the trade-off between the length of a beacon and the rate of transmission. In [24] the author introduced a novel protocol for controlling congestion in VANETs that combines congestion identification and control methods. This mentioned protocol dynamically adjusts the broadcast frequency and the beacon's power of every vehicle to ensure that its application necessities are completely satisfied while managing the created channel load.

A. Overview on Existing Congestion Control strategies applied in VANETs

Table I lists the foremost features of the popular congestion control strategies obtained from the literature.

1. AIMD: In [13], the TCP's AIMD (Additive-Increase & Multiplicative-decrease) approach was employed for controlling the congestion in VANETs, according to [25]. The AIMD law is implemented for the rate of transmitting the message.

2. AC3: In [14], the Adaptive transmit-power Cooperative Congestion Control (AC3) is recommended to permit vehicles to choose their transmission power autonomously concerning their regional channel congestion. AC3 adopts the concept of limited vehicle's participation towards congestion and discovers a legitimate power reduction for vehicles utilizing the symmetrical value system design.

3. LIMERIC: LIMERIC [12] (LInear MEssage Rate Control algorithm) follows a continuous feedback mechanism to accommodate the flow of a message instead of the limit series behavior that is implicit in the PULSAR strategy. LIMERIC is a scattered algorithm, performed individually by each state in a neighborhood.

4. MD-DCC: In [15], a decentralized joint approach is suggested to control congestion in VANETs known as Message-rate and Data-rate Congestion Control approach (MD-DCC). This approach presents an efficient method of assigning the message-rate as well as data-rate among vehicles to manage congestion and satisfy the requirements of an application.

5. PULSAR: In [16], PULSAR (Periodically Updated Load Sensitive Adaptive Rate control) is proposed to manage the congestion in VANETs. Every vehicle calculates the Channel Busy Ratio (CBR) at the finishing point of a defined time and then correlates the calculated value with the targeted value. When the calculated value is observed to be greater than the targeted value, the congestion is detected.

6. SBAPC: In [17], a novel speed-dependent strategy named SBAPC (Speed-Based Adaptive Power Control) is provided for managing the transmission power of Beacon Safety Messages (BSMs). In this approach, every vehicle dynamically sets the transmission power of the BSM packets based on the present velocity. The primary goal for SBAPC is that with the rise in the vehicle's velocity, the time-to-collision (TTC) with nearby vehicles reduces.

7. VANETomo: In [18], a unique strategy named as VANETomo is introduced, that employs analytical Network Tomography (NT) to understand transmission delays among vehicles. This suggested approach combines an open-loop and the closed-loop congestion control method in a VANET simulation environment. Performance evaluation of the proposed algorithm depicts that VANETomo performs much better than the existing congestion control approaches.

III. Proposed Work

The foremost intention of this paper is to control the data congestion happening in the VANETs environment. To achieve this intention, we formed an suitable route that will be employed to identify data congestion occurring in the VANETs domain. Then the detected data congestion will be controlled through our novel approach. The strategy used to discover route, detection of data congestion, and controlling of detected data congestion in the VANETs environment is mentioned in Algorithm 1, 2, and 3, respectively.

1. Discovery of an appropriate route in VANETs environment

Algorithm 1 is the initial stage for our recommended approach, in which the Node's number, Origin node, Destination node, Cluster Head, and Route table will be considered as the inputs, whereas the discovery of an suitable route from source to target node will be the output for this algorithm.

In the starting, we apply the K-means clustering approach and then generate the RREQ messages, which will be broadcasted by the vehicles to their nearby Cluster Head (CH). Until the destination node is not found, the vehicle keeps broadcasting the RREQ messages and recording the hop-count. When the neighboring CH receives any RREQ message, they will check the conditions. If a nearby CH has the same route that is mentioned in the RREQ message, then the nearby CH will be the destination node, or if a nearby CH is not a destination node but have the route to the destination, then it will provide the route by sending the RREP message to the origin node. If no route is found, then the RREQ message will be re-transmitted to the next nearby CH in the network, and the hop-count will be recorded. If the destination node is found, there is a requirement to update the routing table with the new route. In the last step, calculating the distance among the origin node and target node, if the current route is minimum, then the obtained route will become the final route; otherwise, the whole procedure will be repeated to obtain the next appropriate route.

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Algorithm 1: Route discovery for Detection of Data Congestion in VANETs Environment
Assumptions: Initially set Hop-count = 0
Input: V ← Number of Vehicles; SN ← Source Node; DN ← Destination Node; CH = Cluster Head;
        V-Table = [] // Route table
Output: Route discovery from SN to DN for detection of data congestion in VANETs environment
1. Apply K-mean clustering approach
2. Generate RREQ message; RREQ = [ SN, Hop-count, DN]
3. V transmits RREQ message to nearby CH
4. DN-found = 0 // Set a flag; destination is not found initially
5. While (DN-found ≠1)
6. V1 transmit RREQ to nearby CH and Record Hop-count
7. Nearby CH accepts RREQ and check the conditions
8. If [SN, Hop-count, DN] == Nearby CH [SN, Hop-count, DN] then
     Nearby CH = DN and Nearby CH send RREP to SN
   Elseif
     Nearby CH provides route to DN
   Else
     V1 re-transmit RREQ to other nearby CH and Record hop-count
       If (DN-found = 1) then
         Update V-Table
       Else
         Repeat the above steps
 9. Calculate the distance between SN and DN
       If (Obtained distance is minimum) then
         Current Route become final route
       Else
         Check next route condition
       Endif
      Endif
     Endif
   End While
```

2. Detection of Data Congestion in the VANETs environment

Algorithm 2 receives the simulated QoS data for an obtained route, Mean Square Error (MSE), True Positive (TP), and False Positive (FP) as inputs, before predicting the detection of congestion in VANETs environment.

In the beginning, all the simulated data is uploaded to select three clusters. The Euclidean distance from each set of an attribute to the cluster is calculated. Then, the minimum of all the measured distances is determined. After that, the MSE is calculated for the selected three clusters to tag the clusters as one of the three types: Normal, To be congested, and Congested. Start the propagation system by considering the credentials as a) Machine learning model: Levenberg, b) Count for the hidden layer: 10 to 30, c) Cross-validation standards: MSE. If the training propagation is completed, then save the trained data in the database; otherwise, repeat the above procedure. Upon completing training, we take the next set of data for the classification purpose and use the trained structure. If the classified tag is matched with the trained tag and add it to the TP list; otherwise, add it to the FP list.

Algorithm 2: Detection of Data Congestion in VANETs Environment

Input: Simulated QoS data for obtained route; MSE = Mean Square Error; TP = True Positive; FP = False Positive

Output: Detection of data congestion in VANETs environment

1. Upload simulation data for all simulations
2. Selecting 3 clusters
3. Calculate Euclidean distance for each set to cluster
4. Determine minimum of all measured distances
5. Calculate MSE for selected 3 clusters
6. Tag the clusters as:
   Normal, To be congested, and Congested
7. Start Propagation system
8. Propagation Credentials are:
   a) Machine-Learning Model: Levenberg
   b) Count for Hidden Layer: 10-30
   c) Cross-validation standards: MSE
9. **If** Training-propagation is complete **then**
   Save the trained data in the database
   Else
   Repeat steps from 1 to 8
   If Training completed **then**
   Take the next set of data for the purpose of classification
   Else
   Continue to train
10. **Validation**: For classification purpose, apply trained structure
11. Classified tag compared with Trained tag
    If Match found **then**
    Add in TP list
    Else
    Add in FP list
    End if
    End if
    End if

Algorithm 3: Controlling of Detected Data Congestion in VANETs Environment

Input: CDN = Classified Detected Node; CL = List of Confirmed Safe Nodes; NP = Network Parameters; JV = Judgment Value; N-Per = Node Performance

Output: Controlling the detected data congestion in VANETs environment

For every CDN **do**
  Search in CL
  If (Search found) **then**
    Node verified
  Else
    Node not verified
    If (CDN ≠ Nodes in CL) **then**
      Discard the node
    Else
      Fetch the details of verified node
      If (Node details have NP) **then**
        Record NP
      Else
        Discard node
        If (NP recorded) **then**
          Find JV
        Else
          Continue with other nodes
        Endif
      Endif
    Endif
  Endif
  $JV = \sum_{i=1}^{CL\ node-count} \left(\frac{Normalised\ NP}{CL\ node-count}\right)$
  If N-Per < JV **then**
    Discard node
  Elseif N-Per < JV && N-Per > JV * 85% **then**
    Send the warning message to node
  Elseif N-Per < JV && N-Per > JV * 35% **then**
    Reduce 35% load from that particular CDN
  Else
    Continue with other nodes
    If (35% load reduced from particular CDN) **then**
      Divert the load to other CDNs
    Else
      Continue
    Endif
  Endif
End for

3. Controlling of detected data congestion in high-density VANETs environment

In Algorithm 3, the Classified Detected Node (CDN), List of confirmed safe nodes (CL), Network Parameters (NP), Judgement Value (JV), and Node Performance (N-Per) will be considered as the input whereas managing the data congestion in VANETs will be the output of this algorithm.

In the starting for every CDN, search the CL. If the search is found, then the node is considered to be verified; otherwise not verified. If the node is not verified, we discard the node; otherwise, we fetch the verified node details. If the node's details have NP, then we record its NP; otherwise, we discard the node. After recording the NP of the node, we determine the JV, a judgment value obtained through the mentioned formula given in Algorithm 3. If the N-Per is less than JV, then we discard the node. If there is a situation where N-Per is less than JV, and N-per is more than 85% of JV, then we send the warning message to the node. Also, if there is a situation where N-Per is less than JV, and N-per is more than 35% of JV, then 35% load will be reduced from that particular CDN. When 35% decreases the load, then this load will be diverted to the other CDNs. It is the best approach for controlling the occurrence of data congestion in the VANETs environment.

TABLE II. PARAMETERS FOR SIMULATIONS AND THEIR VALUES

Simulation Parameters	Values
Algorithm	CABS, UO-Tabu, MO-Tabu, VANETomo, and the Proposed Method
MATLAB Version	MATLAB 2016(b) or Higher
Network Simulator	NS-2
Number of Nodes	50, 100, 150, 200
MAC layer	802.11b
Number of Iterations	10,000
Transmission Power	0.2 Watt
Simulation area	1000mx1000m, 1200mx1200m
Vehicle speed (Maximum)	90 Km/h
Vehicle speed (Average)	60 Km/h
Parameters	PLR, Throughput and Delay
Size of Data-Packet	512 bytes

IV. Experimental Results

The VANETs network performance is examined by considering three different metrics, including Packet Loss Ratio, Delay, and Throughput. The metrics for simulations are elaborated in the Table II. Here, the distribution of speeds will be 60 km/hr (average), 70km/hr, 80km/hr, and 90 km/hr

(Maximum). The VANETs characteristics depend on the ratio of the number of nodes chosen and the selected simulation area. If the VANETs simulation region is very large then the congestion chances are low even on increasing of the vehicular nodes. These simulation parameters have been chosen based on the existing literature survey. Many researchers are working with the NS-2 simulator and MATLAB tool for implementing their research work. This simulation environment is employed to analyze the execution of four various algorithms: CABS, UO-Tabu, MO-Tabu, and VANETomo, along with our recommended approach.

A. Throughput

Throughput is defined as the volume of data packets that are favorably gathered by the destination node in the provided time-period and describes the network data-rate condition. Fig. 1 illustrates the throughput for the CABS, UO-Tabu, MO-Tabu, VANETomo, and the Suggested algorithm in Kbps. In this graph, the specified algorithm throughput is displayed concerning varying node's number. Simulation performed with 50 nodes, the Thr-CABS have 4.4 Mbps, Thr-UO-Tabu has 4.6 Mbps, Thr-MO-Tabu has 4.8 Mbps, Thr-VANETomo has 5 Mbps, and Thr-Proposed has 6.2 Mbps. Simulation performed with 200 nodes, the values of throughput rises as follows the Thr-CABS has 27 Mbps, Thr-UO-Tabu has 32 Mbps, Thr-MO-Tabu has 34 Mbps, Thr-VANETomo has 36 Mbps, and Thr-Proposed has 39 Mbps. Our above-proposed algorithm significantly exceeds the other algorithms.

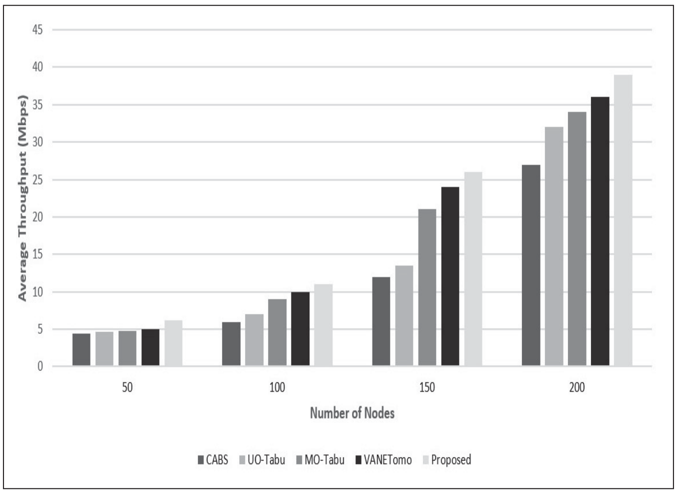

Fig. 1. Throughput for our proposed approach increases in comparison to the other existing approaches

B. Packet Loss Ratio

This metric is defined as the portion of packets dropped throughout transmitting packets to the destination node from the origin node. This situation arises during the interference in the VANETs environment. Fig. 2 describes the PLR for the CABS, UO-Tabu, MO-Tabu, VANETomo, and our Suggested algorithm in percentages. This figure represents the specified algorithm's PLR concerning the node's number. Simulation performed with 50 nodes, the PLR-CABS is 0.070%, PLR-UO-Tabu is 0.040%, PLR-MO-Tabu is 0.035%, PLR-VANETomo is 0.034%, and PLR-Proposed is 0.021%. Simulation performed with 200 nodes, the values of PLR rise as follows PLR-CABS is 0.180%, PLR-UO-Tabu is 0.090%, PLR-MO-Tabu is 0.044%, PLR-VANETomo is 0.039%, and PLR-Suggested is 0.027%. Our proposed algorithm produces the least PLR outcomes in correlation to the other algorithms.

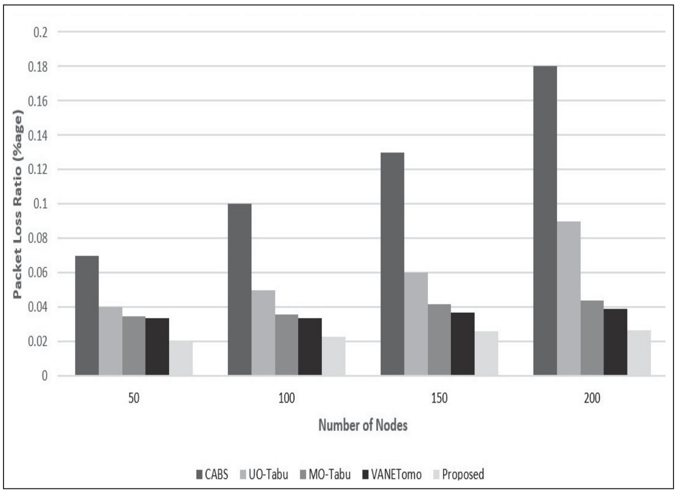

Fig. 2. Packet Loss Ratio for our proposed approach decreases in comparison to the other existing approaches

C. Average Delay

This metric is defined as the extra time demanded by the data packet to arrive at the target node other than the original time. This situation occurs when the packets encounter obstacles, such as collisions or blockage in the VANETs environment. Fig. 3 depicts the average delay for the CABS, UO-Tabu, MO-Tabu, VANETomo, and Suggested algorithm in terms of milliseconds. In the mentioned graph, the specified algorithm's delay is depicted concerning the different node's number. Simulation performed with 50 nodes, the Delay-CABS is for 24 ms, Delay-UO-Tabu is for 22 ms, Delay-MO-Tabu is for 21 ms, Delay-VANETomo is for 20 ms, and Delay-Proposed is for 18 ms. Simulation performed with 200 nodes, delay values increase as follows: the Delay-CABS is for 108 ms, Delay-UO-Tabu is for 28 ms, Delay-MO-Tabu is for 25 ms, Delay-VANETomo is for 23 ms, and Delay-Proposed is for 21 ms. Our recommended work provides much more stable outcomes in contrast to the other algorithms. With the increase in node number, our suggested algorithm has a lower average delay in correspondence to the other specified algorithms.

By examining the above-obtained outcomes, our suggested algorithm is demonstrated effective by outperforming the other existing algorithms. Our strategy's foremost purpose is to determine the route that will be employed to identify data congestion in the VANETs domain and then control the detected data congestion. Through our suggested approach, outstanding

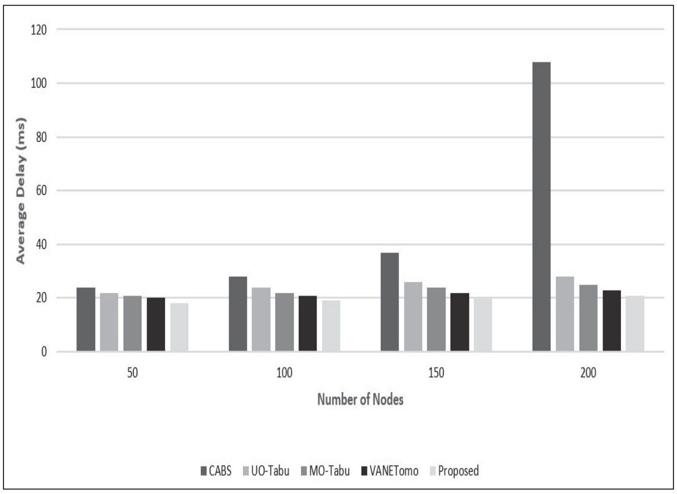

Fig. 3. Average Delay for our proposed approach decreases in comparison to the other existing approaches

results are achieved in terms of throughput while maintaining the PLR and average delay low. Through our recommended approach, we detect the data congestion in VANETs before controlling it.

The complete results that are obtained by using the proposed algorithm are mentioned below. By employing the 50 nodes, 6.2 Mbps for the Throughput, 0.021% for Packet Loss Ratio, and 18 ms for the Delay parameter are achieved. By employing the 200 nodes, the Throughput, Packet Loss Ratio, and Delay parameters are increased to 39 Mbps, 0.027%, and 21 ms respectively. By evaluating the obtained results, the proposed algorithm performs much better than the existing algorithms even on increasing of the nodes. Only three parameters are used in this paper to justify the accuracy of the proposed algorithm, this is considered as the limitation for the paper. But in the future more novel parameters such as Routing overhead, Packet Delivery Ratio, Jitter, and many more such parameters can be used for the justification of the recommended algorithm.

V. Conclusion and Future Work

The vehicle's safety is enhanced by creating reliable communication among all the vehicles traveling on the roadways. It is entirely achievable if the foremost hurdle named the data-congestion occurring in the VANETs domain is properly managed and controlled. This paper initially creates a suitable route that will be applied for the identification of data congestion in the high-density VANETs environment, and then a novel approach is introduced for controlling that detected congestion. Consequently, the network performance after including our recommended approach is examined by considering three discrete parameters, named Packet Loss Ratio (PLR), Delay, and Throughput. These metrics are used to review the performance of four complex algorithms named CABS, UO-Tabu, MO-Tabu, VANETomo, along with our proposed algorithm. The outcomes revealed that our suggested algorithm provides much better outcomes in contrast to the existing algorithms. The proposed algorithm gives better throughput along with the least value for PLR and average delay. Many researchers are working in this domain and created several effective and productive strategies to control data congestion in the VANETs environment. For future work, there is a requirement for selecting more novel parameters that will be used as the justification for the proposed algorithm. Also, developing advanced strategies for controlling the detected data congestion in the VANETs environment so that communication between the vehicles can be more reliable and secure.

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