Congestion Control Method Using Vehicular Congestion Index by Reducing Messaging Broadcast Rate

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Abstract. The aim of this research paper is to design an approach for congestion control in Vehicular Ad Hoc Networks (VANETs) by utilizing a vehicular congestion index to reduce messaging broadcast rates. VANETs are innovative technologies that enable vehicles to communicate via wireless connections, revolutionizing transportation systems. Messages in VANETs are prioritized based on their purpose: Beacon Message/Cooperative Awareness Message (CAM), Emergency Message/Decentralized Environmental Notification Message (DENM), and Surrounding Information. DENM has the highest priority, followed by CAM, and lastly Surrounding Information. The Vehicular Congestion Index (VCI) measures the number of CAM messages received by a vehicle within a specific time and region. When the number of messages exceeds a predefined VCI threshold, an Adaptive Beacon Rate Control mechanism reduces the broadcasting rate of beacon or CAM messages. This conserves bandwidth, allowing for the prioritized transmission of emergency messages during roadblocks, accidents, or other critical events

Keywords: VANET, CAM, DENM, VCI, ABRC, OBU, Congestion control, Safety.

1. INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) are decentralized networks derived from the intelligent transportation system (ITS). They function as a type of mobile ad hoc network (MANET), where vehicles establish communication through on-board units (OBU). Congestion arises when channels become saturated due to nodes competing for the same channel, and as vehicle density rises, congestion occurrences and channel collisions also increase. Congestion adversely affects VANET performance by causing delays and packet loss, particularly for safety messages. Therefore, it is imperative to implement congestion control mechanisms to enhance VANET performance. By reducing delays, minimizing packet loss, and improving overall reliability and safety, congestion control measures can significantly optimize VANETs for their users. These enhancements promote efficient communication, better traffic management, and heightened driver awareness in VANETs, resulting in enhanced road safety and improved transportation systems.

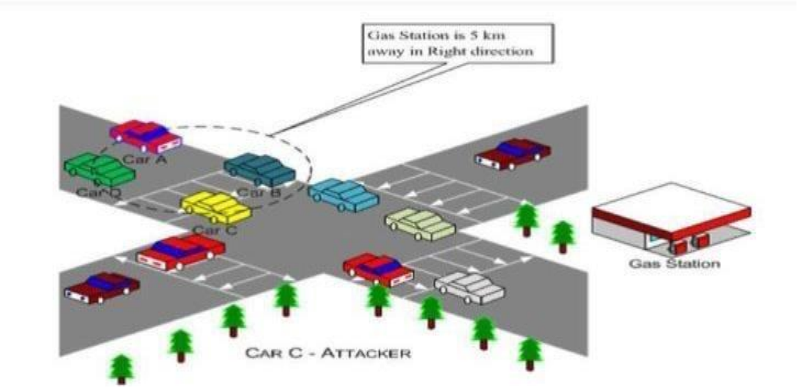


Figure 1: Message Broadcast

Implementing VANET on a large scale poses several challenges that need to be addressed effectively: Congestion control is a significant challenge in VANET implementation, requiring efficient utilization of network resources to mitigate traffic congestion. Managing network connections between vehicles and infrastructure is crucial. The intermittent connections resulting from high vehicle mobility or packet loss in vehicular networks must be minimized. Future VANETs necessitate high mobility and accurate location awareness of participating vehicles to handle emergency situations effectively. Each vehicle should possess accurate position information about other vehicles in the network. The anticipated proliferation of heterogeneous smart vehicles poses another challenge for future VANETs. Managing diverse vehicle types and their sporadic connections requires careful attention.

Preserving user data content and location privacy is a constant concern. Vehicles communicating within the infrastructure must provide users with control over which information to exchange and what to keep private. Future VANETs must support network intelligence by accommodating a multitude of sensors installed in vehicles. The edge cloud plays a crucial role in collecting and pre-processing data before sharing it with other parts of the network. Vehicular Ad hoc Networks (VANETs) have a diverse range of applications, but their primary objective revolves around ensuring safety during vehicle journeys. Currently, car collisions stand as one of the leading causes of fatalities, and the projection that they will become the third leading cause by 2025 emphasizes the pressing need for effective solutions. This presents a substantial business opportunity for various services such as infotainment, traffic advisory, and car assistance. Car manufacturers, driven by user polls and feedback, are actively investigating, and developing highly sought-after applications to address these safety concerns. These applications include Post Crash Notification (PCN), which enables prompt response and assistance in the aftermath of an accident, Congestion Road Notification (CRN) to provide real-time traffic updates, Lane Change Assistance (LCA) to assist drivers in safe lane changes, and Cooperative Collision Warning (CCW) to alert drivers about potential collisions. By harnessing the power of VANET technology and implementing these advanced applications, the aim is to significantly enhance road safety, reduce accidents, and save lives.

2. LITERATURE REVIEW

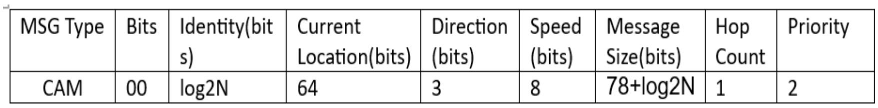
In [2], a TDMA cluster-based MAC protocol called TCMAC is proposed for VANET, specifically designed for intra-cluster communication. The protocol combines a centralized cluster management approach with TDMA slot reservation to ensure that vehicles can send and receive non safety messages even in high traffic density conditions, without compromising the reliability of safety message transmission. However, a drawback of this approach is that when vehicle density is low, the percentage of missed direct messages remains low. In [3], an adaptive LDMA (ALDMA) scheme is introduced,which enables medium access for vehicle nodes based on their time, geographical location, and a predefined location-to-time mapping. The scheme employs two messagedissemination techniques: even triggered multi-hop relaying and periodic one-hop broadcast. By utilizing ALDMA, the flood-induced broadcast storm problem is mitigated to some extent. In [4], a space division multiple access (SDMA) scheme is proposed, providing medium access to users based on their geographical location in space. Real-time location information is necessary for users to benefit from SDMA, which divides the geographical space into smaller subspaces.The scheme ensures collision-free access to the communication channel and facilitates communication address resolution among users. However, a challenge of SDMA is that its bandwidth efficiency decreases when the number of users decreases. In [5], the Vehicular Self-organizing MAC (VESOMAC) is introduced as a TDMA protocol that takes into account vehicle location and movement to order MAC slots based on relative vehicle position, aiming to minimize multi-hop delivery delay. However, VESOMAC's effectiveness is limited to oversimplified scenarios. In [6], the MAC protocol is extended to incorporate an enhanced distributed channel access (EDCA) mechanism for traffic prioritization. The extension ensures timely dissemination of highly critical emergency messages by assigning appropriate service differentiation parameters. However, a challenge of EDCA is its lack of strict prioritization enforcement, rendering it ineffective when the traffic consists solely of safety messages. In [7], the TDMA-Based MAC protocol VEMAC is proposed, specifically designed for VANET scenarios. VEMAC supports efficient one-hop and multi-hop broadcastservices on the control channel by using acknowledgementsand eliminating the hidden terminal problem. It reducestransmission collisions caused by node mobility on the control channel by assigning disjoint sets of time slots to vehicles moving in opposite directions and road-side units. However, a requirement of the VEMAC protocol is that eachnode must transmit its packet only during its designated timeslot, even when it has no data to transmit.

3. PROPOSED SCHEME

The implemented architecture utilizes a congestion control method to manage the transmission of Cooperative Awareness Messages (CAMs) in Vehicular Ad Hoc Networks (VANETs). When a vehicle receives multiple Basic Safety Messages (BSMs) from other vehicles, it calculates a vehicular congestion index. The Adaptive Beacon Rate Control (ABRC) mechanism is employed to regulate the frequency at which CAMs are broadcasted by the On-Board Units (OBUs) within a vehicle. CAMs contain essential details about a vehicle's location, speed, heading, and other attributes, serving to enhance situational awareness and enable cooperative driving. The ABRC mechanism dynamically adjusts the beaconing rate of CAMs based on the density of vehiclesin a specific area. By adapting the CAM broadcast rate, the system can effectively mitigate congestion issues andoptimize the dissemination of relevant information among vehicles and Roadside Unit (RSUs).

Types of Messages

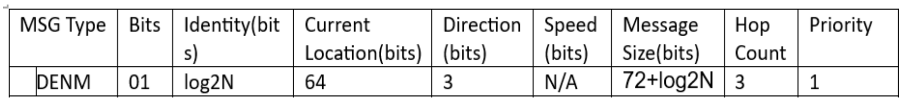
Here, messages will be delivered based on priority.Messages will be divided into 3 types:



MSG Type	Bits	Identity(bits)	Current Location(bits)	Direction (bits)	Speed (bits)	Message Size(bits)	Hop Count	Priority
CAM	00	log2N	64	3	8	78+log2N	1	2

Figure 2. Type I Message Figure 2 denotes the details of Type I message.

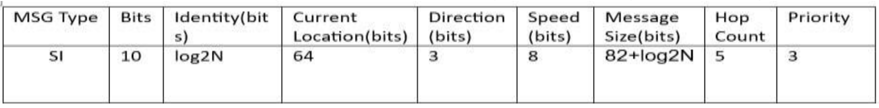
Beacon Message/Cooperative Awareness Message (CAM) whose priority level is 2. CAM which is denoted in algorithm as Type I messages provide information about the surrounding environment of a vehicle, including its location, direction, speed. These messages are sent within the network coverage area. They are given medium priority. When the Vehicle Congestion Index (VCI) is greater than 5, the Adaptive Broadcast Rate Control (ABRC) mechanism sends CAM messages.The size of the Type I message is 78 + log2N bits, whereN represents the number of vehicles in the region.



MSG Type	Bits	Identity(bits)	Current Location(bits)	Direction (bits)	Speed (bits)	Message Size(bits)	Hop Count	Priority
DENM	01	log2N	64	3	N/A	72+log2N	3	1

Figure 3. Type II Message Figure 3 denotes the details of Type II message.

Emergency Message/Decentralized Environmental Notification Message (DENM) whose priority level is 1. DENM which is denoted in algorithm as Type II messages convey critical information about major congestion or roadblocks to vehicles within arrange of 3 hops. They are given the highest priority. These messages provide details such as the sender's identity, current location, direction. When the VCI is equal to 5, the ABRC mechanism sends DENM messages. The sizeof the Type II message is 72 + log2Nbits.



MSG Type	Bits	Identity(bits)	Current Location(bits)	Direction (bits)	Speed (bits)	Message Size(bits)	Hop Count	Priority
SI	10	log2N	64	3	8	82+log2N	5	3

Figure 4. Type III Message. Figure 4 denotes the details of Type III message.

Surrounding Information (SI) whose priority level is 3. SI which is denoted in algorithm as Type III messages deliver information about traffic conditions, indicating that the road is clear for faster travel and about the surrounding entertain areas (like cafe, gas station). Thesemessages can propagate up to 5 hops. They are given thelowest priority. When the VCI is less than 5, the ABRC mechanism sends Surrounding Information. The size of the Type III message is 82 + log2N bits.

PRPOSED WORK

When a car (vehicle) receives several CAM messages from other cars, then a vehicular congestion index is developed. Adaptive Beacon Rate Control (ABRC) is a mechanism used in VANETs to control the frequency in which Cooperative Awareness Messages (CAMs) are broadcasted by On-Board Units (OBUs) in a vehicle. CAMs are messages that contain information about a vehicle’s location, speed, heading, and other attributes, and are broadcasted to other vehicles and Roadside Units (RSUs) to improve situational awareness and enable cooperative driving.

The ABRC mechanism adjusts the beaconing rate of CAM based on the density of vehicles in a specific area.

```
1. Set DEFAULT_VCI to 5
2. Set MIN_TYPE_I_BROADCAST_RATE to 0.5 seconds
3. Set MAX_TYPE_I_BROADCAST_RATE to 5.0 seconds
4. Set REDUCTION_FACTOR to 0.1
5. Set INCREASE_FACTOR to 0.1
6. Initialize current_vci to DEFAULT_VCI
7. Initialize current_type_I_broadcast_rate to MAX_TYPE_I_BROADCAST_RATE
8. If current_vci > DEFAULT_VCI then
   a. Calculate new_type_I_broadcast_rate as max(current_type_I_broadcast_rate*(1-REDUCTION_FACTOR), MIN_TYPE_I_BROADCAST_RATE)
   b. If new_type_I_broadcast_rate < current_type_I_broadcast_rate then
      i. Set current_type_I_broadcast_rate to new_type_I_broadcast_rate
      ii. Print "Reducing type_I broadcast rate to current_type_I_broadcast_rate seconds"
   c. End if
9. else if current_vci == DEFAULT_VCI then
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        a. Send type_II message
        b. End if
10. else if current_vci < DEFAULT_VCI then
        a. Calculate new_type_I_broadcast_rate as min(current_type_I_broadcast_rate * (1 + INCREASE_FACTOR), MAX_TYPE_I_BROADCAST_RATE)
        b. If new_type_I_broadcast_rate > current_type_I_broadcast_rate then
            i. Set current_type_I_broadcast_rate to new_type_I_broadcast_rate
            ii. Print "Increasing type_I broadcast rate to current_type_I_broadcast_rate seconds"
        c. End if
        d. Send type_III message
        e. End if
11. Set current_vci to DEFAULT_VCI
```

4. RESULT

In our research work, OMNET++ was used to run simulations that visually demonstrated the dynamic transmission of messages. The simulation graphics effectively represent the various network communication processes, providing useful insights into our research findings.

Figure 5. Type I Beacon Message

Figure 6. Type II Emergency Message

Figure 7. Type III Surrounding Information Message.

Figure 5

The image in figure 5 shows the simulation of beacon message.

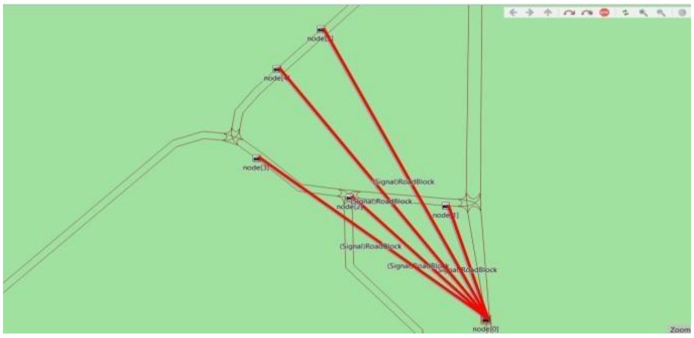

Figure 6

The image in figure 6 shows the simulation of emergencymessage.

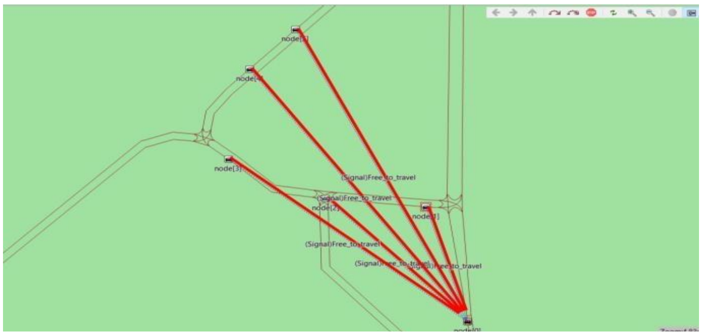

Figure 7

The image in figure 7 shows the simulation of surrounding information message.

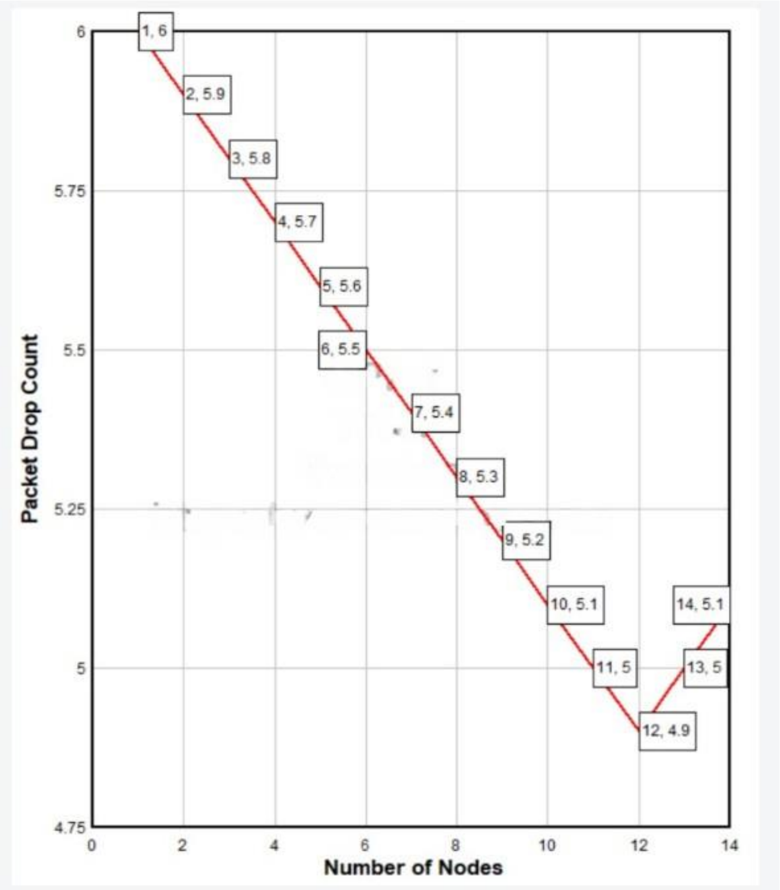

Figure 8. Packet Drop Count vs Number of Nodes

The graph between Packet Drop Count and Number of Nodes is plotted using D-Plot. The line denotes the number of message drops per node.

5. CONCLUSION

Therefore, by analyzing various congestion control approaches and understanding their advantages and disadvantages we can conclude that congestion control is very crucial for VANET to work properly and efficiently. It is necessary to keep developing and finding new solutions to all the given cons and challenges for VANET to become mainstream as it ensures road safety, saves time, reduces pollution & traffic jams, and most importantly also saves human lives. And our approach of congestion control method using Vehicular Congestion Index (VCI) accomplishes this task with good efficiency. There are still much research work going on in VANET to optimize this technology as much as possible as it will be handling one of the very crucial aspects of human lives that is transport. So, some of the important upgradation can be: Average traffic speed as VANET holds the information to all the vehicles in each area it can also provide us with the average traffic speed, so that we can roughly determine our estimated time of arrival to our destination. With this, we will be able to detect fast-approaching vehicles from behind in time, which will improve the user's awareness of traffic.

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