Journal of Theoretical and Applied Information Technology

15th November 2023. Vol.101. No 21

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

A RANDOM EARLY DETECTION (RED) TECHNIQUES TO OVERCOME THE CONGESTION PROBLEM IN VEHICULAR ADHOC NETWORKS (VANETS)

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ABSTRACT

A vehicular ad-hoc network, also known as VANET, is described as one of the most challenging domains when providing an intelligent transport system (ITS). VANET is a critical application area for the mobile ad-hoc network also regarded as MANET. However, the effectiveness of VANET depends on the ability to detect congestion and resolve security issues to ensure effective and efficient services are provided to the users. This paper aims to examine random early detection techniques applicable in determining congestion issues in VANETS and propose the working framework useful for handling congestion in VANET via the provision of effective queue management approaches. The approach presented in this study paper is known as Node Based Throughput (NBTH), which focuses on evaluating the throughput of nodes. In this case, the approaches were examined and scrutinized with different parameters, such as end-to-end throughput delays and packet loss associated with the density nodes.

Keywords: *VANET, MANET, Congestion, vehicular network.*

1. INTRODUCTION

Ad hoc networks have a unique characteristic: they can be described as a network without infrastructure but a pool of wireless nodes deprived of static infrastructure. Mobile Ad-hoc Network, also known as MANET, is a subcategory of Ad-hoc network. In addition, there is a category of MANET that is accountable and provides adaptation for the diverse approaches, especially for the intelligent transport infrastructure (ITS) known as the vehicular ad-hoc network (VANET) [1]. The main feature of the VANET is ensuring effective communication between pavement apparatus and vehicles. Recently, studies have focused on understanding the development of VANET that permits the development of exchanges between cars and other vehicles as well as roadside units (RSUs) through the application of the wireless sensor mounted on each vehicle connected to the same network. A high and critical topology exists, making VANET one of the most charismatic research areas. The system is reliable in providing secure, reliable, and safe vehicular systems. In this case, two of the outstanding communication types in the plan include vehicle-to-vehicle and the communication between vehicles and infrastructure. The VANT system has some distinctive features such as;

- The expectable nature of vehicles' movement is given that flow is only two ways of traffic in every street.
- Using an existing network, vehicles can provide sufficient electric power to the road sensors or apparatus sensing

- The information from the source to the destination is provided by the VANET broadcast instead of relying on unicast communication.

However, working with network layers is associated with numerous problems, but the most outstanding issue is congestion. Thus, there is a need to implement approaches to detect and manage network congestion, especially in VANET. In congestion handling, the main question one deals with is how to see congestion in a network. As soon congestion is detected, applying a close loop methodology is prudent to handle the congestion issue [2]. One should note that when the presented weight exceeds the designated capacity of the node in the management of packets or when the network experiences an incompetent link for managing quantity packets, it leads to congestion in the network. It is also possible to result in bandwidth congestion due to channel fading. Another problem caused by network congestion is the reduced effectiveness of data rates, primarily due to the loss of information.

Further, congestion accounts for the drop-in packets at the buffers, leading to amplification of delays and loss of energy, which leads to signal retransmission. It also means that the network would experience bias, especially for nodes that fail to negotiate substantially in hops collection. The result is that there would be a significant reduction in accomplishing a lifetime of networks. The proposed approach for congestion detection in this paper is the node-based approach. The use of this approach is critical because the method calculates the throughput nodes and uses them as a comparison with the expected value of throughput. MANET is a temporary network where various nodes are arranged in a particular way whenever necessary. The paper's organization ensures coherence and flow of information. The next section of the report provides research methodology where a discussion of the approaches used in data collection is explained. The following team will be dedicated to results and discussion, followed by a section on the conclusion.

1.1. Problem Identification

Numerous causes of traffic congestion; some are caused by predictable factors such as road construction, while other reasons are highly unpredictable. Some example of unexpected cause of congestion is road accidents and weather changes. Most road users may not know about congestion which makes them join it, making it even more severe. Drivers usually waste a lot of time before traffic congestion clears after removing the cause of the accident. Enabling drivers to understand traffic conditions beforehand allows them to find alternative routes, saving time and fuel. Giving many drivers this ability to avoid congestion, especially those caused by incidents, makes it easy to avoid traffic congestion by ensuring that only a few vehicles are affected. The result of this information sharing is that it makes it possible for drivers to use road infrastructure efficiently and effectively.

In most cases, congestion arises due to drivers' behavior and the lack of road information. Currently, various approaches exist to report traffic issues, including pictures from the helicopters showing where the congestion starts, where it ends, and the speed at which vehicles travel on various roads. There is a need to provide drivers with the information required to overcome issues of congestion, such as;

- Identification of the congestion and where it occurs, and its boundaries
- The information needs timely relay to drivers on time, especially those heading towards congestion.

1.2. Existing Solutions

Given the existing problem, some individuals and institutions have tried to implement measures to overcome congestion and resolve the issue. The current solution relies on route selection and static systems that give traffic information [3]. In such a system, there is a high probability of the system failing to provide reliable information, primarily because it bases its data on static map data. However, in recent years, some traffic systems strived to implement real-time data to help select the route. The data for this real-time information is usually provided by commercial service providers like NAVTEQ [4]. These providers typically rely on humans, cameras, and other road infrastructure to relay the given information and, at the same time, maintain a database for existing traffic conditions. The reliance on these sources of information makes the existing traffic congestion solution unreliable and cannot provide essential real-time information. It is also not a cost-effective approach to traffic management, especially in developed parts of the country and major cities. For example, there are only 2,000 traffic cameras in major cities like New York. The data they provide usually need to be translated by humans or special software to give information about congestion [5].

The focus of this write-up is to provide a solution that relies on using vehicles as the nodes in VANET and ensure that they are helpful in the data collection process, which focuses on enhancing the collection of valuable information in the determination of real-time traffic [6]. The information collected for this work is simply based on the V2V communication and the data integrated into every vehicle's navigation system. The approach also relies on a routing algorithm that can detect congestion in the most efficient way possible.

1.3. Related Work

There is numerous research on the area of congestion using VANET conducted over the years and usually focuses on vehicular traffic simulations [8] [9][10], while other researchers depend on multi-hop routing [11] [12]. Some researchers relied on VANETs in their work which led to the idea of discovering and disseminating traffic congestion data [13] [14]. In this case, one can use the wireless network on vehicles to create an ad-hoc wireless network capable of finding and disseminating traffic data and information about congestion.

A collision-avoidance system is critical because it is designed to collect information about real-time incidences and share it with the vehicles along the route to help them avoid collisions [15]. Other researchers in the area provide insights into the working mechanism of VANET. For instance, some researchers examined the efficacy of the VANET networks and provided a summary of the routing protocols that make the operations effective [16]. In a different research, authors cite that the effectiveness of VANET in transportation functions properly due to the availability of the dedicated short-range communication (DSRC), and when vehicles connect to such networks, the ability to solve significant traffic problems increases [17]. In this case, the connected cars, also described as VANETs, carry two different communication devices known as on-board units OBUs) and an additional device is known as roadside units (RSUs) [18]. The location of OBU devices is usually inside the vehicles, while RSUs are on strategic points within the highway. The Vehicle-to-infrastructure communication occurs between the internal OBUs and the external RSUs, while vehicle-to-vehicle contact occurs via the OBUs to OBUs devices [17]. The communication between vehicles is classified into various channels of different megahertz ranging from 5850-5925, and 75 of these channels are registered under the federal communication commission [18]. A summary of the spectrum range is shown in figure 1 below.

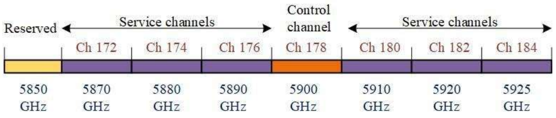


Figure 1:DSRC channel of communication

The vehicles are installed with a control channel that transfers critical data about the road, such as the occurrence of accidents to other cars in the same range. Thus, vehicles utilizing V2V communication use wireless access in a vehicular environment (WAVE). The same technology applies to the V2I type of communication. Research indicates that the efficacy of VANET in congestion control requires different approaches due to particular requirements such as increased mobility, the quality of the channel, and the use of heterogeneous devices.

1.4. Contributions

As noted in the previous section, the use of VANET in predicting and controlling congestion requires extra features due to its unique characteristics. The communication between vehicles in mobile states is described as MANET, a Mobile Ad-hoc network [19]. Studies show that relying on VANET in the application of the Intelligence Transportation System is a tedious process [20]. Thus, the characteristic of VANET causes congestion in the network due to the high density of vehicles using the web. The contribution of this work is to present random early detection techniques (RED) helpful in overcoming the congestion problem in VANET networks. The proposed protocol for the effectiveness of the approach is the Medium Access Control (MAC).

2. RESEARCH METHOD

As noted in this study, detecting congestion in ad hoc mobile networks is easy by examining the entire space around the nodes, also known as neighborhoods. There is a need to experiment to show how MRED and NRED neighborhood helps in enhancing congestion detection. Mobile random early detection, also described as MRED, is useful compared to neighborhood random early detection (NRED), which is vital and applicable in this research to understand clustered networks. The clustered heat is applied because it enables load reduction, which occurs through the calculation of the mean size of the queue, also described as channel utilization. The sizes of queues in cluster head, also known as member nodes, help determine network congestion level.

The method applied in this study was cluster-head congestion detection which operates after identifying cluster heads. For congestion detection in ad hoc networks, figure 2 below represents a simple overview of the flow diagram useful in head selection.

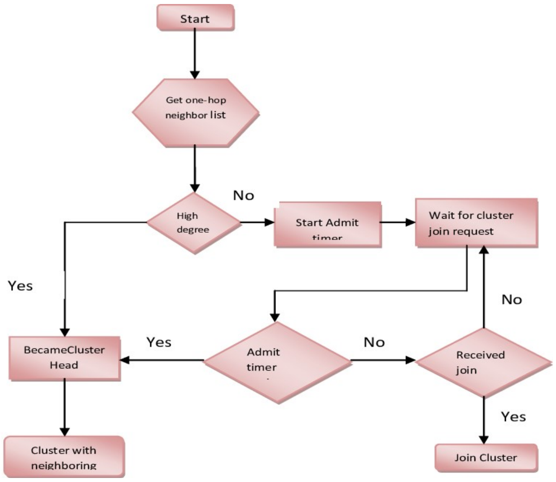


Figure 2: Cluster head selection flow chart

As shown in the figure, channel utilization is key to congestion identification. This study utilized five channels shown in the figure and include; transmit, receiving, carrier sensor when a busy sensor is in virtual form, and idle. There are three categories in each radio stats. The first and second channels examine nodes to complete channel application; channels 3 &4 contribute to node neighbor utilization, and the fifth channel is usually assumed to be empty. In this approach, the original NRED state where three channels utilization. The total utilization of various channels is denoted as (U_{busy}). The transmission ratio was denoted as (U_{tx}). The time for each channel is represented as T_{tx}, $T_{ix,}$ $T_{cs,}$ and T_{idle}. In this case, letting T_{int} represent the total time spent in every state, then the ratio of utilization is represented in the three equations below.

$$U_{busy} = \frac{T_{int} - T_{idle}}{T_{int}}$$

$$U_{tx} = \frac{T_{tx}}{T_{int}}$$

$$U_{rx} = \frac{T_{rx}}{T_{int}}$$

Where,

T_{int} = $T_{tx} + T_{rx} + T_{cs} + T_{vcs} + T_{idle}$.
U_{busy} = cluster-head queue size.
U_{tx} = outgoing queue channel bandwidth usage, and
U_{rx} =incoming queue channel bandwidth usage

In this case, the early congestion stage occurs when the network appears to surpass the set threshold for the U_{busy} Threshold number.

$$q = \frac{U_{busy} * W}{C}$$

Where;

W represents the bandwidth of the channel in bps

C indicates the mean packet size represented in bits.

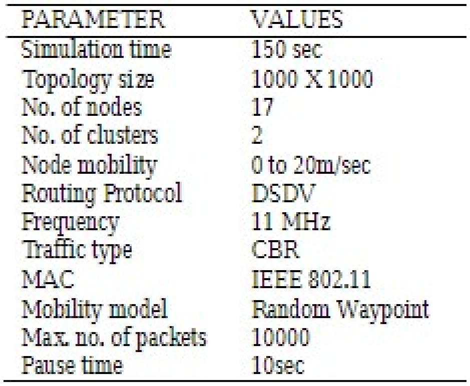
In this case, the mean size of the queue is determined using the equation below;

$$avg = (1 - wq) * avg + wq * q$$

In addition, the study utilized a special algorithm to determine the cluster gateways and explain the different cluster head nodes. The selected algorithm uses random numbers between 0 and 1, which are generated using the function ([0, 1]) in a pseudo code. This study hypothesizes that it is possible to understand random congestion detection by examining cluster changes and node mobility. The null hypothesis is that there is a direct relationship between changes in pause time and mobiles nodes. The experiments were conducted as shown.

2.1. Experimental Scenario

The scenario presented using the proposed algorithm consist of seventeen mobile nodes and two gateways examined on a network simulator. The simulator-2 (NS2) was applied on a rectangular topology covering one hundred by one hundred meters squared. The experiment was conducted for two and a half minutes. The data are shown in the outcome figure attached below.



PARAMETER	VALUES
Simulation time	150 sec
Topology size	1000 X 1000
No. of nodes	17
No. of clusters	2
Node mobility	0 to 20m/sec
Routing Protocol	DSDV
Frequency	11 MHz
Traffic type	CBR
MAC	IEEE 802.11
Mobility model	Random Waypoint
Max. no. of packets	10000
Pause time	10sec

3. RESULTS AND DISCUSSION

It should be noted that the nodes in the cluster occur in the form of mobile nature, meaning that the nodes and heads change their location randomly and unpredictably. With the 17 mobile nodes and topology of 1000 square meters, the change in mobility is directly proportional to the change in pause time for mobile nodes, as shown in the figure below.

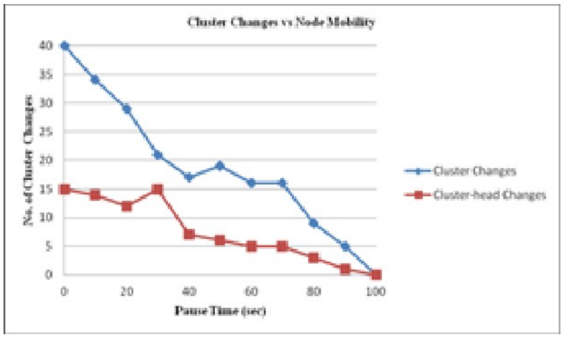


Figure 3: Cluster changes compared to node mobility

The values presented in figure x above are shown in table 1, below

Table 1: Changes in the cluster against node mobility

S. No	Cluster head changes		Cluster changes	
	Number of head changes	Pause time (sec)	Number of time	Pause time (sec)
1	15	0	40	0
2	15	20	50	20
3	7	40	17	40
4	5	60	16	60
5	3	80	10	80
6	0	100	0	100

In this case, the queuing level for clusters in the MRED scheme represents parameters that impact the performance. Using the equation

$$q_{avg} = (1 - W)q_{avg} + W_q,$$

one gets the values represented in table 2.

Table 2: queue against time

Time	0	10	20	30
Average (estimates) Queue size	100	200	90	20
Real mean queue	100	200	35	32

The graph above shows changes in nodes and cluster sizes. There is a direct association between the queue size and the pause, which implies that a reduction in queue size results in a significant reduction in pause time.

The results observed showed that there are different levels of fairness indices, and the value varies depending on changes in the fairness indices. The value varies from 0 to 1, and in exposed areas, the fairness indices are higher than 0.95 of the throughput due to two major causes. The first reason is a drop caused by NRED utilizing the channel. In this case, a packet drop somehow reduces or wastes bandwidth, indicating a small wastage factor in MRED. In contrast, NRED indicates two different values for instantaneous throughput. The results can be represented as shown in figure 4 below.

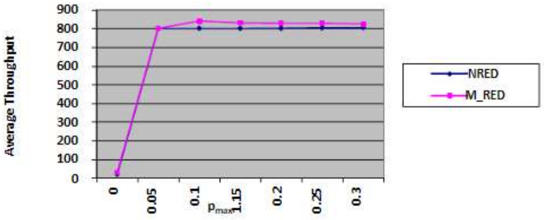


Figure 4: throughput and P value.

The results showed that the throughput shown in MRED compares to values shown in NRED, and in such cases, a 3% improvement of MRED is observed. As shown in the figure, case of MRED, clustering and queuing lead to improvement in results. In different topologies, several neighborhood bottlenecks are represented spontaneously, as shown in figure 5 below. The following sections compare the results to the literature.

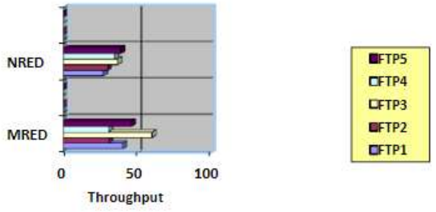


Figure 5: performance n MRED and NRED.

The results of the experiment are consistent with the null hypothesis. In other words, the results indicated that changes in queue size directly relate to the real pause time, which is useful in predicting the overall congestion issues in the network.

3.1. Ad-Hoc Networks (MANET and VANET)

The main concern in this work is the communication between vehicles and infrastructure, which is based on mobile ad-hoc networks (MANET). VANET applies the MANET to enhance its performance. Mobile Ad-hoc networks enable vehicles to effectively share data with other cars on the road and simultaneously communicate with the infrastructure. Thus, two common types of networks facilitate the operation of VANETs: the infrastructure-based and mobile ad hoc networks, as shown in figures 6 and 7 below.

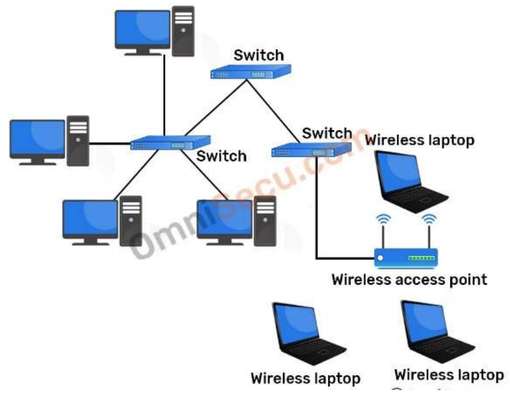


Figure 6: infrastructure-based network

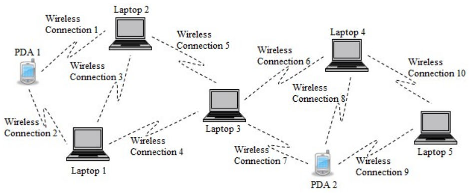


Figure 7: Mobile ad-hoc network

Most research focuses on the MANET areas, such as routing. However, studies show that MANETS has no specific property considerations to operate in the transport layer effectively. The findings in this study show that the existing congestion control protocol, transmission control protocol (TCP), is not efficient in dealing with issues occurring in MANETs. This is because TCP was developed with an internet design [21]. The implication of this is the need for a more comprehensive congestion control which is a primary problem for both MANET and VANET.

3.2. Congestion Related Problems

The findings indicate several issues associated with MANETs that relate to congestion. One identified problem is throughput degradation; another example is the massive fairness issues [22]. These issues originate from the routing of MAC. Other researchers show that the same problems arise from transport layers [23] [24]. In this case, there are several practical solutions to the existing problem.

3.2.1. VANET characteristics and application

Understanding the significant characteristics of vehicular ad-hoc networks and how one can use them in congestion detection is essential. There are distinctive characteristics of the VANET network that help detect the congestion problem. Typically, this is regarded as a unique ad-hoc network that allows moving motor vehicles to apply it in different functions. Some of the significant traits of the network.

- It has very high mobility. This network has no fixed nodes since they are in constant and speedy motion. The movement makes it difficult to accurately predict the exact location of a node and almost impossible to uphold nodes' privacy.
- Another distinct feature of the network is the network topology. This topology is based on the idea that it has a fixed network, but the vehicles sing it is not static. In other words, vehicles keep changing their positions on the road to the movement.
- The other trait of VANET is that it has an unbound network size. In this case, one can execute it in different locations such as cities, more than one city, and even in a country or more countries. The implication is that VANET is unbound in terms of geographic location.

- Additionally, the network is characterized by its frequency of information changes. The data is collected using an ad-hoc network which enables the collection of all the required data from the nodes as RSU [23]. The availability of beacons enhances the exchange of information in this case.
- The last characteristic of the network is that it utilizes wireless communication. Using a wireless network in information transmission usually enhances communication through electromagnetic waves.

This type of network makes it possible to apply in different areas, especially communication. It usually has three kinds of various applications classified into safety-related applications, some that are non-safety-related and those regarding traffic management.

3.2.2. Congestion control structures

This study found that congestion is one of the main issues affecting the efficacy of the network, especially in high-density frequencies and topologies. Control of congestion targets fair and dependable access but applies different parameters. In addition, this study found that detection of congestion in VANET operates through collecting data from congested links at any given interval. Once detected, congestion is followed by control methods for congestion mitigation. In figure 8 below, a congestion scenario is presented. The figure shows a system of congestion of the DSRC-based approach.

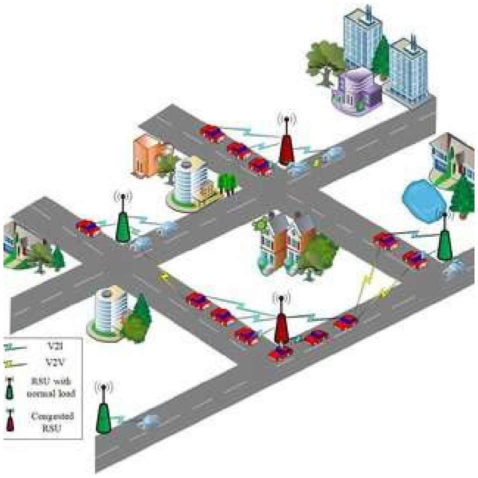
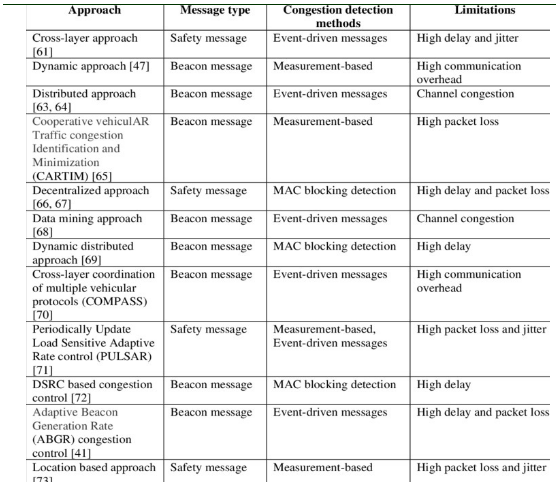


Figure 8: A congestion scenario of DSRC

Another detection technique relies on either events or priority techniques. Researchers recommend using adaptive episodic beaconing, which relays time gap information [25]. Another proposed approach is the dynamic and distributed technique for congestion detection, which senses how a given channel is utilized and compares it to the set threshold [25]. The entry sets at about 70% in most cases, especially in wireless messaging channels. Setting this threshold ensures no congestion in the media even when the number of vehicles increases.

Measurement techniques for detecting congestion also rely on capacity and channel use. How a channel is used at any moment is compared to a set value that determines the presence of congestion. As shown in figure 4, the technique is based on the DSRC method for vehicular nets. The main advantage of the two approaches discussed in this section is cost-effectiveness and loss of very low packets. Further, it is possible to detect congestion through the MAC blocking approach that relies on channels liked based on the messages transmitted on various beacons [24]. The design of VANET is to help improve traffic safety because it allows vehicle vehicular communication and enables the vehicle to infrastructure linkage. In this case, VANET ensures that each vehicle in the network exchanges information, leading to congestion in the network when there are numerous vehicles.

Given that numerous methods and techniques are helpful in congestion detection in VANET, it is only vital to provide a summary of each approach found after the research. The strategies presented in figure 6 below show different methods and how each transmits information. In addition to the system, the figure also indicates message type, congestion detection technique as well disadvantages of each.



Approach	Message type	Congestion detection methods	Limitations
Cross-layer approach [61]	Safety message	Event-driven messages	High delay and jitter
Dynamic approach [47]	Beacon message	Measurement-based	High communication overhead
Distributed approach [63, 64]	Beacon message	Event-driven messages	Channel congestion
Cooperative vehiculAR Traffic congestion Identification and Minimization (CARTIM) [65]	Beacon message	Measurement-based	High packet loss
Decentralized approach [66, 67]	Safety message	MAC blocking detection	High delay and packet loss
Data mining approach [68]	Beacon message	Event-driven messages	Channel congestion
Dynamic distributed approach [69]	Beacon message	MAC blocking detection	High delay
Cross-layer coordination of multiple vehicular protocols (COMPASS) [70]	Beacon message	Event-driven messages	High communication overhead
Periodically Update Load Sensitive Adaptive Rate control (PULSAR) [71]	Safety message	Measurement-based, Event-driven messages	High packet loss and jitter
DSRC based congestion control [72]	Beacon message	MAC blocking detection	High delay
Adaptive Beacon Generation Rate (ABGR) congestion control [41]	Beacon message	Event-driven messages	High delay and packet loss
Location based approach [73]	Safety message	Measurement-based	High packet loss and jitter

Figure 9: Summary of detection methods

3.2.3. Proposed solution

Different approaches fit the random early detection techniques to overcome congestion in VANET networks. As seen in this study, using V2V and V2I structures is essential and critical in unexpected and early detection methods. Each method found in this case shows that there is a need for each technique to rely on random messages, mainly because vehicles are in constant motion while the network remains constant. Therefore, the realistic proposed approach is called Traffic Congestion Detection (TCD), based on V2V communication. Techniques for detecting traffic congestion (TCD) are becoming an essential component of traffic management systems. They can be viewed as a first step towards addressing traffic congestion issues, giving useful input for traffic management systems to predict and mitigate the negative impacts of traffic congestion. TCD can detect traffic congestion based on a single traffic feature (for example, speed, occupancy, or flow).

In this random technique, vehicles are mandated to collect facts, process them, and use them in decision-making regarding the traffic in a given location. The algorithm of this technique applies different steps. The first step examines the occurrence of congestion, the second step examines speed monitoring, and the third step of vehicle decision. The fourth step involves broadcasting, while the fifth and last are about congestion detection. In this algorithm, vehicles detect congestion by analyzing the received message from other cars. Completing this algorithm means that all vehicles on the route receive a warning message from other cars that prompts them to act. Although this technique solely depends on V2V communication, it applies V2I exchange of information in examining and scrutinizing the received message before making decisions. However, depending on the V2V, communication alone is vital and reliable at cost practical application. It is cost-effective because it does not need investment in infrastructure, and the price is also distributed to different car owners, making it a pocket-friendly solution. It is also distributed because no central infrastructure is applied, which translates to ease of deployment.

3.2.4. Limitations and assumptions

The main limitation of the proposed solution is that it has high deployment value and usually comes with limited coverage. It is also assumed that V2V communication does not require additional infrastructures such as beacons and a centralized network. The other assumption is that the solution solely depends on the vehicle for translating information into valuable data supporting decision-making.

4. CONCLUSION

As noted in this study, VANET is a particular ad hoc network that enables motorists to detect and overcome congestion issues. There are numerous approaches for random congestion detection in VANET, each depending on the type of message sent. The effectiveness of VANET depends on the Mobile ad hoc network, also known as MANET. Each algorithm used in this network depends on communication between vehicles and between vehicles and infrastructure. In other words, there is V2V and V2I communication. The proposed solution, in this case, is the Traffic congestion technique (TCD) which solely depends on V2V communication. Although the approach has numerous advantages, such as cost-effectiveness, it is also limited in terms of coverage.

The presented algorithm in this article can detect congestions with high accuracy and a short detection time, but the city operators still need additional data to decide on the best mitigating measures. In future research, the researcher might look at how the TCD algorithm propagates congestion along the city's road network. By providing details about the possibly affected roadways and their expected timing of the congestion arrival, this study on congestion propagation gives city operators more insight into the effects of the observed congestion.

ACKNOWLEDGEMENTS

This research was supported by the Center for Research Excellence and Incubation Management, Universiti Sultan Zainal Abidin.

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