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A Comparative Study of Congestion Control Algorithm in Vehicle Ad-hoc Networks in Aleppo City

Mohammad Hammadi[1], Souheil Khawatmi[2], Bader eddin Kassab[3]

[1]pursuing a M. S. Computer Networks at the Faculty of Informatics Engineering, University of Aleppo, Syria.
[2]associate professor at the Faculty of Informatics Engineering, University of Aleppo, Syria.
[3]associate professor at the Faculty of Informatics Engineering, University of Aleppo, Syria.

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Abstract - *Many research agencies in transportation seek to find safe ways by equipping vehicles with devices that collect information about the vehicle and sense the road condition. After that, this information is delivered to central units for processing and giving appropriate orders to the vehicles. Vehicular Ad-hoc Network (VANET) is a special part of Mobile Ad-hoc Network (MANET) and a step towards Intelligent Transportation Systems (ITS). It ensures road safety, facilitates traffic management, and provides travelers with some safety and entertainment applications. With the rapid increment in the auto drive vehicles over time, VANETs are suffering from congestion due to the enormous amount of data exchanged between vehicles, negatively affecting Vehicular ad-hoc Networks' performance. For this reason, many researchers have resorted to developing and discovering techniques and algorithms to reduce this congestion and detect and treat it in a timely manner to prevent collisions and congestion that lead to traffic accidents and disasters.*

Key Words: **VANETs, congestion control algorithm, NCaAC, SAE-DCC, Adaptive Power Level Control Algorithm**

1. INTRODUCTION

The great development of cities and transportation has created several problems, including pollution and traffic congestion, which make life uncomfortable. These problems prompt researchers to develop cities and make them smart, link vehicles to each other by establishing a network, and control vehicles and traffic jams[1]. Vehicular Ad-hoc Network (VANET) concerns the lives of road travelers and road safety by reducing traffic accidents. However, VANET networks suffer from frequent interruptions in inter-vehicle links. One of the main reasons for these interruptions is the dynamic nature of VANET caused by frequent changes in layout and the locations of mobile nodes. That poses challenges to inter-vehicle communications increased by the large amount of data spread between vehicles on limited bandwidth. On the other hand, the dynamic layout of VANET networks causes congestion in the communication channel leading to lost messages, delays, and a lack of quality of service. Because of these problems experienced by Vehicular Ad-hoc Network, researchers have found and developed algorithms and techniques to control congestion caused by vehicles density. In this research, we study three algorithms, NCaAC, SAE-DCC, and APLCA used to control congestion. Then, we simulate these algorithms using appropriate tools and apply the simulation to the city of Aleppo as a study case.

2. System architecture and network operation

The VANET consists of many vehicles (nodes), and the number of vehicles connected to VANETs exceeds 750 million vehicles worldwide daily [2]. These vehicles need a central controller to control them, and they can communicate with each other by using short waves (5.9GHz) as an ad-hoc connection. The routers used to help vehicles to communicate are called Road Side Units (RSUs). They forward packet between vehicles all the way, and at the same time, they are connected to other VANET networks. Each vehicle contains an On Board Unit (OBU) communication unit that can connect to RSU via short-range radio signals, Dedicated Short-Range Communications (DSRC), and other devices. As shown in Fig. 1, vehicles can communicate with each other and with roadside units.

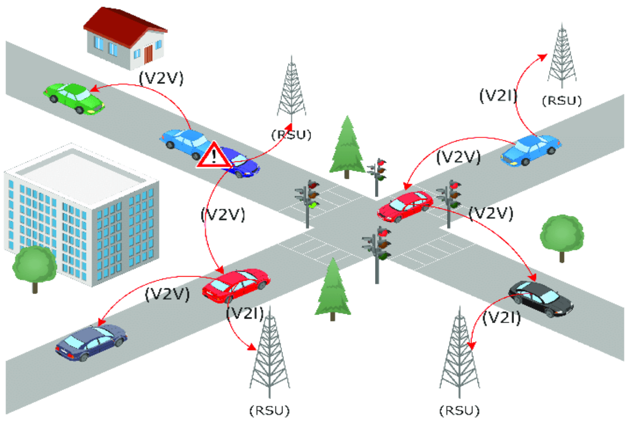

Fig -1: Communication in Vehicular Ad-hoc Network

3. Congestion in VANET

The significant number of connected vehicles can cause congestion due to the messages exchanged between vehicles [3], which in turn causes a bottleneck in the network, leading to ahigh packet loss rate and time delays in data transmission. For this reason, many researchers have proposed some solutions to mitigate preventing network throttling, either by improving existing routing protocols or by developing algorithms that detect and control congestion [4].

4. Congestion control algorithms

Most congestion control algorithms consider two main factors individually or combine both, named hybrid algorithms. These factors are as follows:

1. Message transmitting rate: the algorithm controls either the number of periodic messages by reducing or increasing the messages according to the state of the channel or the size of the transmitted messages [5].
2. Capacity to send messages: the algorithm increases or decreases the message transmission power according to the state of the channel [5].

4.1. Network Coding aware Admission Control (NCaAC)

In this algorithm, the RSU categorizes messages as high and low priority [6] Then, it transfers the messages to the control channel and the service channel, respectively, as shown in Fig. 2. If the number of nodes in the area increases or there is a serious traffic situation, the RSU can balance the load with nearby RSUs to reduce network congestion. The advantages of VANET's congestion network coding are the efficient use of bandwidth and the low packet loss at all nodes. However, NCaAC undergoes higher energy consumption and costs while load balancing can redistribute loads to nearby RSUs [7].

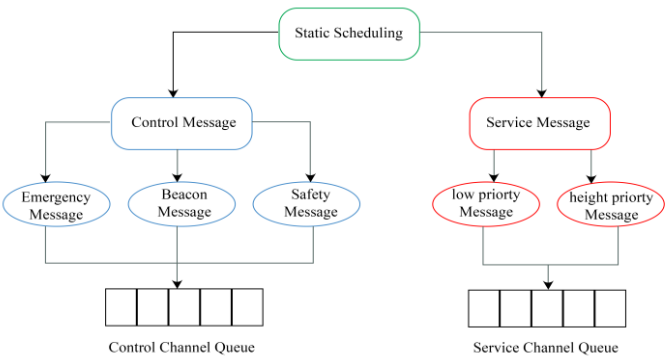

Fig -2: Control message and services message in Network Coding aware Admission Control algorithm

4.2. Society of Automotive Engineers International-Decentralized Congestion Control (SAE-DCC)

Various Decentral Congestion Control (DCC) algorithms have been proposed to address the critical congestion problem, which can be reactive or proactive DCC techniques [8]. DCC adapts various transmission factors (message rate, data rate, etc.) to keep the channel load below the threshold according to three main approaches: firstly, it changes the transmission rate by sending fewer messages per second. This approach causes a delay due to the period between messages. Secondly, it changes the transmission strength, so the message does not go far. In this situation, Beacons and Acknowledgments sent by vehicles are reduced. Thirdly, DCC is tuning both previous factors into hybrid congestion control technology [9]. SAE-DCC adjusts the message rate according to the number of vehicles within a 100-meter range and adjusts the transmit power according to the Channel Busy Ratio (CBR) in case there are no events. If a serious event occurs, SAE-DCC generates a Basic Safety Message (BSM) - a beacon message used for Safety in V2X communications - and transmits it instantaneously at the maximum permissible transmit power[10]. A BSM message comprises two parts. As shown in Fig. 3 The first part is the basic part of the BSM packet, which includes basic status information (vehicle speed, location, time stamp, number of messages, brake system status, etc.). The second part is included in the BSM packet only. If no emergency event happens, the BSM packet is created periodically or based on the congestion control algorithm. However, if the condition of an emergency event is met, an empty BSM packet must be created for the accelerated event and the Event Flag in the second part of the BSM will be marked.

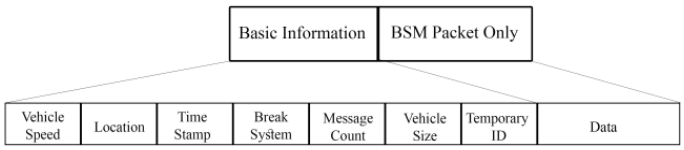

Fig -3: Content of Basic Safety Message in VANET BSM

4.3. An Adaptive Power Level Control Algorithm (APLCA)

In this algorithm, the energy consumption of sending messages is adopted so that messages are sent with different capacities depending on the state of the channel [9]. As a result, if congestion occurs in the channel, the power is reduced; thus, the message does not reach long distances in the network - alleviating congestion. APLCA showed good results in the case of cities with high density of cars, but in low density or on highways, there was a Significant of data loss, which negatively affected network performance in general.

5. Simulation and result

The simulation was carried out using three tools, and an area within Aleppo city was adopted. The first tool we used is the OpenStreetMap tool, which helps download custom maps in XML format, as shown in Fig. 4. Then, we converted the XML files into a specific format to be included

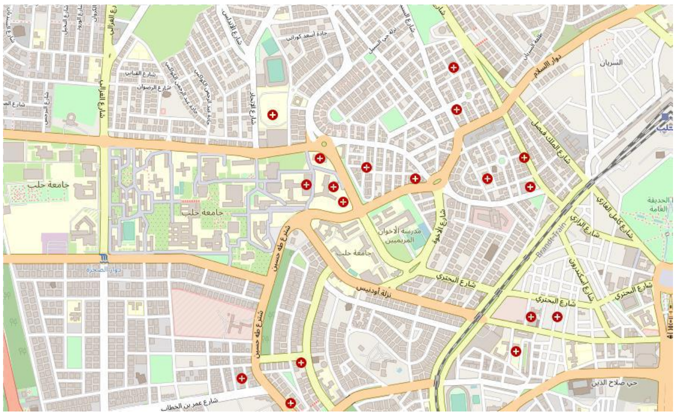

Fig -4: A part of Aleppo city using open street map

In the SUMO simulator – the second tool - .As shown in Fig. 5, the SUMO simulator is an open-source vehicle network simulator that supports different types of vehicles and roads in addition to traffic lights at intersections and priorities. Road networks can be imported either manually or through the OpenStreetMap tool.

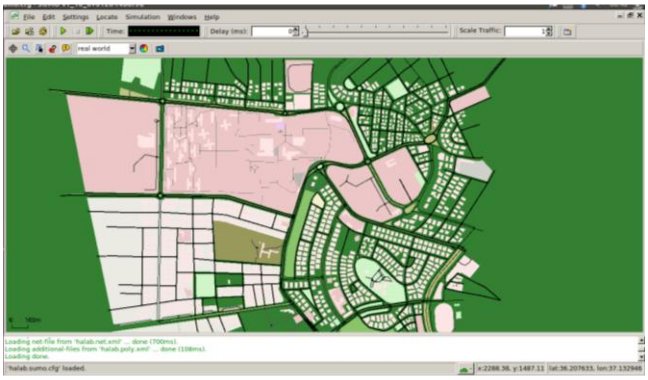

Fig -4: A part of Aleppo city using sumo tool

The third tool we used in our experiment is NS2 (Network Simulator). It is a well-known network simulator used to simulate the movement of nodes within the network, generate tracking files for nodes, and analyze the results of these files. Fig. 6 shows the random movement of nodes within the generated paths based on the Aleppo map.

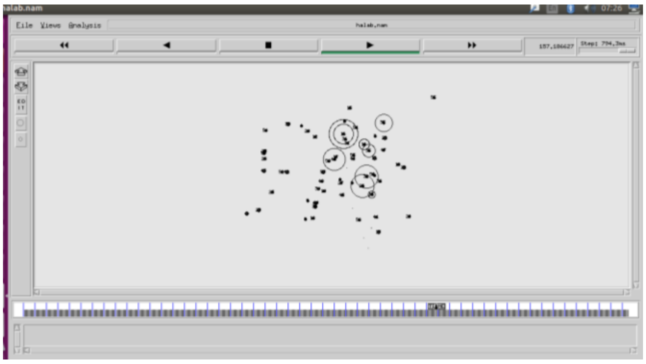

Fig -6: Simulating cars movement using NS2

The experiment parameters used in the simulation were set as shown in Table -1. After setting up and running the simulation, several performance measures have been measured, as follows:

Table -1: experiment parameters used in the simulation

parameters	value
Simulation area	Aleppo City
Node average speed	40-80 km/h
No. of Vehicles	20 - 100
Transmission range	350 m
Packet Size	512 bytes
Traffic Type	CBR
Simulation Time	300 s

5.1. End-to-end (E2E) delay

The E2E delay of every single packet is defined as the sum of the delays that occurred in a series of nodes the whole way from the source to the destination. As the number of vehicles increases, the delay increases due to the increment in the number of messages exchanged between nodes. This parameter is very important for choosing the best algorithm performance regarding E2E delay. Chart-1 shows the simulation E2E delay for the three algorithms

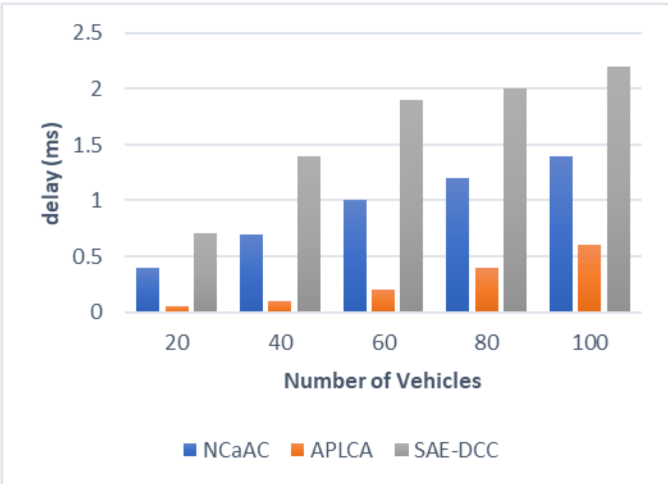

Chart -1: End To End Delay

5.2. Packet Delivery Ratio (PDR)

The packet delivery ratio is the rate of the average number of packets received at the destination to the total number of packets sent from the source to this destination.

The results show that the percentage of data delivery increases with the number of vehicles to a certain extent.

However, when a high density is reached, the PDR decreases due to the large number of exchanged messages and network congestion. Chart-2 shows the simulation results for the three algorithms in terms of PDR.

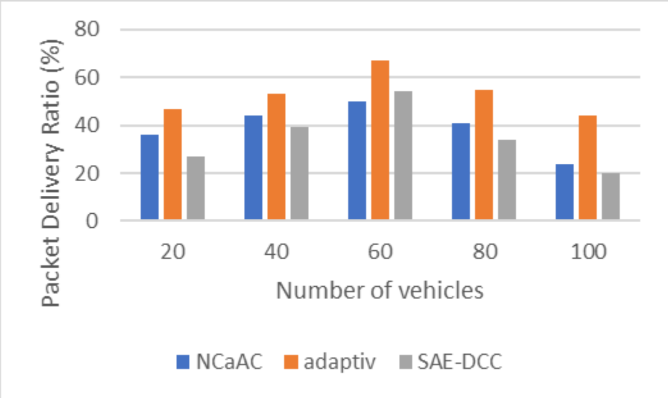

Chart -2: Packet Delivery Ratio

5.3. Throughput

Network throughput is the amount of data successfully transferred from one place to another during a given period of time, usually measured in bits per second (bps) and its multiples. Throughput tells the user how often messages successfully reach their destination, representing a practical measure of actual packet delivery rather than theoretical packet delivery. The throughput increases directly with the number of vehicle . According to the results in Chart-3, the SAE-DCC algorithm showed the best productivity compared to the rest when the number of compounds ranges between 20 and 100.

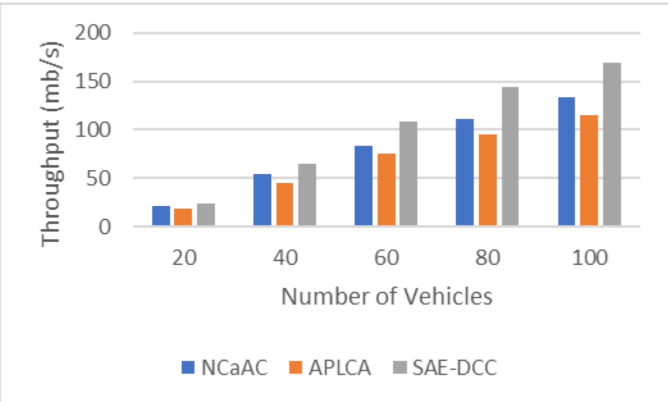

Chart -2: Throughput

6. Conclusion and Future Work

In this paper, we evaluate and compare the performance of three congestion control algorithms by simulating them within a near-real environment and the results show the superiority of the adaptive power level algorithm compared to the rest of the algorithms concerning the End-to-End delay, PDR, and Packet Loss Rate. However, when it comes to the network throughput, We note that the rate of throughput is low compared to the rest of the algorithms, because it reduces the number of messages sent by reducing the energy of sending these message, and this in turn leads to a reduction in the number of messages in the whole network, which explains the low throughput and also explains the reduction in delay time and the increase in the percentage of PDR In future research, we will modify the adaptive power level algorithm to reduce congestion in vehicle Ad-hoc networks, improving their performance and thus increasing road safety and providing the necessary services for travelers.

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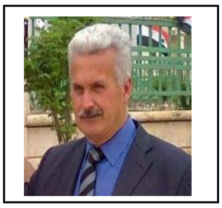
BIOGRAPHIES

Mohammad Hammadi received his B. S. degree from the Faculty of Informatics Engineering, AlBaath University, Syria in 2018. He is currently pursuing a M. S. Computer Networks at the Faculty of Informatics Engineering, University of Aleppo, Syria. His current research interests include VANET communication.

Souheil Khawatmi received his B. S. degree from the Faculty of Computer Engineering, University of Aleppo, Syria in 1982 and PhD degrees from the Institute of saint-Petersburg for Communication, Germany in 1989. He is currently an associate professor at the Faculty of Informatics Engineering, University of Aleppo, Syria. His current research focuses on Computer Networks and Wireless Communication.



Bader aldin Kassab received his B. S. degree from the Faculty of Computer Engineering, University of Aleppo, Syria in 1986 and PhD degrees from the Institute of saint-Petersburg for Communication, Russia in 1992. He is currently an associate professor at the Faculty of Informatics Engineering, University of Aleppo, Syria. His current research focuses on the management telecommunication centers.