International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 7 | July 2023 www.irjet.net p-ISSN: 2395-0072

A Proposed Methodology to Reduce Congestion in Vehicle Ad-hoc Networks by Determining the Direction of Vehicles in Aleppo city

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Abstract - *The dynamic nature of vehicular ad hoc network (VANET) induced by frequent topology changes and node mobility, imposes critical challenges for vehicular communications. Aggravated by the high volume of information dissemination among vehicles over limited bandwidth, the topological dynamics of VANET causes congestion in the communication channel, which is the primary cause of problems such as message drop, delay, and degraded quality of service. To mitigate this congestion, congestion control algorithms were used in vehicle networks. These algorithms depend on several factors to reduce congestion, including the message sending power factor or the message sending rate factor. In some algorithms, the two factors were combined together. In this article, an improvement mechanism was proposed on an algorithm based on the power factor to control congestion. The results showed the effectiveness of the mechanism and its positive impact on the vehicle network, which positively affects the performance of vehicle networks in general.*

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

1.INTRODUCTION

A Vehicular Ad Hoc Network (VANET) is a type of mobile ad hoc network (MANET) that enables communication among vehicles and between vehicles and roadside infrastructure using wireless communication technologies. VANETs have emerged as a promising solution to improve road safety, traffic efficiency, and passengers' comfort, among other benefits.

In a VANET, each vehicle is equipped with a wireless communication device that allows it to exchange information with other nearby vehicles and roadside infrastructure. The communication can be either vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) depending on the type of communication and the network's architecture. Vehicles can share information such as their location, speed, acceleration, and direction, as well as traffic conditions, road hazards, and weather conditions.

VANETs can be classified into two types: infrastructure-based and infrastructure-less. In an infrastructure-based VANET, communication is facilitated through roadside units (RSUs) that are deployed along the road network. RSUs act as access points and relay messages between vehicles and the central infrastructure. In contrast, in an infrastructure-less VANET, communication is entirely peer-to-peer, and vehicles self-organize and coordinate their communication without the need for any centralized infrastructure.

VANETs face several challenges, including limited bandwidth, high mobility of vehicles, and security and privacy issues, among others. Nevertheless, VANETs have the potential to revolutionize the transportation system by enabling various applications such as collision avoidance, traffic management, emergency response, and infotainment services.

Overall, VANETs are an exciting and rapidly evolving field of research, and their potential benefits make them a promising technology for the future of transportation.

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.

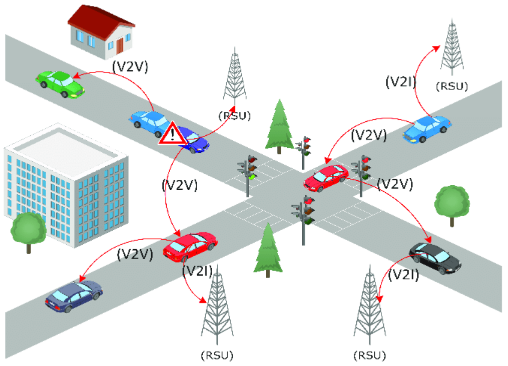

Fig -1: Communication in Vehicular Ad-hoc Network

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. Related works

In [5] the researchers relied on the rate of messages sent and the priority of these messages, so that they are classified into two parts, creating a frame for each type of message:
The first type is Safety_message, and this type is given high priority. The second type is the rest of the other messages Other_message It is given lower priority than public safety messages. All messages are placed in both frames depending on the type of message and then the messages in the highest priority frame are sent at a high rate, while the rest of the messages are ignored or transmitted at a low rate. The researchers used productivity coefficients (Throughput) and E2E end-to-end time delay and packet delivery ratio (PDR) as performance metrics for this proposed algorithm, which showed an overall performance increase but increased data loss when the proportion of cars in the network increased.
In [6] the researchers presented a proposed algorithm that depends on balancing the load in the network using the RSU , that is, when a certain congestion occurs within the scope of a certain RSU , load balancing occurs with another RSU so that the vehicles are later directed to less crowded roads or paths, and thus the congestion in the network has been reduced. The research used performance measurement parameters (throughput, delay, and the rate of delivery of data packets) and an improvement in network performance was noted, but one of the most important disadvantages of this algorithm lies in the long distance between RSUs or the presence of obstacles such as buildings, and it was not implemented on the V2V network structure, as it was achieved Only in V2I architecture and therefore the proposed algorithm is not suitable for urban environment.
In [7] This algorithm proposed by researcher Wei is a hybrid algorithm that uses transmission rate and transmission power together. It adjusts the transmission rate of messages according to the vehicle density and thus maintains the stability of the channel state. Important messages such as public safety messages are sent at the highest capacity available to be delivered in the required time and without a significant time delay. The simulation results showed the ability of the proposed algorithm to control the channel well and improve the network performance, but at a high density of vehicles there was a relatively large percentage of data loss, and this percentage increases with the increase in the number of vehicles. In [8] the researcher relied on the message transmission capacity factor, so that messages are sent with different capacities depending on the state of the channel. That is, if congestion occurs, the transmission capacity is reduced, and thus the message does not reach long distances in the network, and thus congestion is reduced. The results of benchmarking the algorithm showed good performance in the case of cities and high vehicle density, but in low density areas or on highways, there was a percentage of data loss, which negatively affected the overall network performance. In [9] he researchers based the algorithm proposed here on the strategy of prioritizing the delivery of BSM messages to nearby vehicles, which can be achieved by using a low transmission power level instead of continuous transmission at a power of 200 mw. When using less transmission capacity, network congestion will be reduced and packet delivery will be increased, but the awareness of distant vehicles will be reduced, and therefore vehicles will not be able to know if a specific incident has occurred in order to take appropriate action.

5. Suggested method

The basic algorithm in this research is based on adjusting the power rate of sending messages based on the network condition and the state of the communication channel
If there is no congestion in the channel, it sends messages with a high power of approximately (20 milliwatts), and if congestion occurs in the channel It reduces the transmission power to (5 milliwatts), but even transmitting with a power of 5 milliwatts to all vehicles in the network within a specific transmission range, it will lead to congestion in the communication channel when the number of vehicles reaches a certain limit because the algorithm sends to all vehicles within the transmission range [10].

Therefore, we will modify the algorithm so that it does not send to vehicles traveling in the opposite direction of the vehicle, and therefore we will reduce the number of messages sent within the network, and thus this will reduce congestion in the network. Figure (2) shows the flow chart of the basic algorithm without modification, and we note that the algorithm sends to all vehicles regardless of the vehicle's direction.

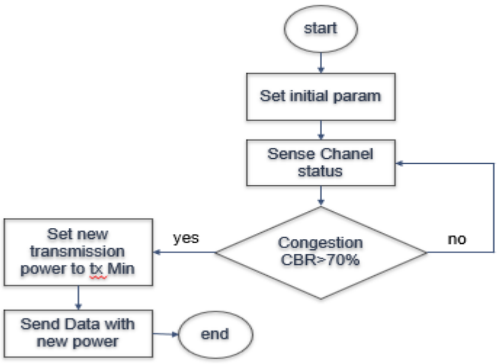

Fig -2: Flowchart of the adaptive power level control algorithm

Figure (3) shows the proposed method for modifying the basic algorithm so that the algorithm first determines the direction of vehicles before sending messages, and then only sends messages to vehicles that are in the same direction.

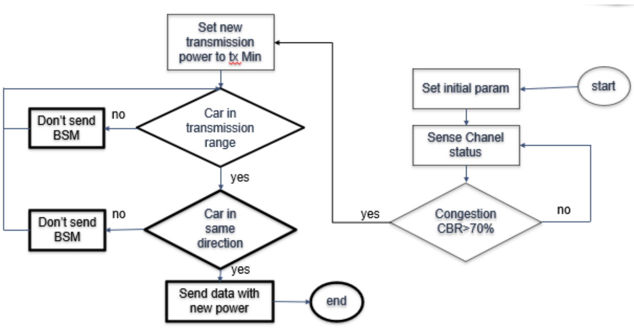

Fig -3: The improvement of the basic algorithm

The initialization phase begins with determining the near and far transmission ranges in meters for the current vehicle. In practice, the Tx transmission capacity does not depend solely on the target distance, but also on additional factors such as weather conditions, obstacles, and vehicle density. The distance between vehicles is calculated depending on the energy of the vehicle's transmission using the inverse square law [11], which is a physical law that describes the decrease in the radiation power or the force resulting from the transmission by an inverse amount of the square of the distance between the source and the receiver, and it applies to various types of radiation and transmission, including Electromagnetic radiation and transmission in vehicle networks. We certainly expect that vehicles at a distance d relative to vehicle v will receive a Basic Safety Message (BSM) as follows:

• All BSM messages are at a distance less than or equal to the specified range and when in the same direction.

• High capacity BSM messages located at a distance greater than the specified range.

• You will not receive any BSM messages if the distance is greater than the specified range, at low power, or when in the opposite direction.

6. Determine the direction of the vehicle

The direction of the vehicle is determined using one of two methods:

6.1 The traditional way :

It is calculating the distance between vehicles using the Euclidean method, which depends on calculating the distance between two points during certain time intervals, so that if the distance is decreasing, this means that the two vehicles are in opposite directions, and in this case the message is not sent; And if the distance is almost constant, then this means that the two vehicles are in the same direction, and thus the message will be sent [12].

There are several cases that need to be discussed:

- If one vehicle is faster than the other and they are in the same direction, the distance will decrease (no-transmission condition) but the message must be sent because the two vehicles are in the same direction.
- The two vehicles are in opposite directions, but the distance is increasing. That is, after the two vehicles intersect, the distance between them will increase (in the case of sending a message), but in this case the message should not be sent.
- The two vehicles go one way (transmission state).
- The two vehicles are in opposite directions (in case of non-transmission).

To solve this problem, we proposed in this research a mathematical model that depends on the distance between the two vehicles by determining the direction in order to be able to determine the status of the message if it is in a state of transmission or not.

First, we will deduce the model by the physical method, and the symbols used in the laws are:

If X is the coordinate of the mover, which is the algebraic distance from the principle on the horizontal axis. We will have for example:

Xa1 is the coordinate of car a at the first moment t.
Xb2 is the coordinate of car b at t +1 second.

V: is the speed of the mover, and it is a positive algebraic value when the car is moving towards the axis and negative in the opposite direction. We will have for example:

Vb is the speed of the second car (+15 with the axle and -15 against the axle).

The time function of uniform rectilinear motion is given by:

$$X=Vt+X_0 \quad (1)$$

And for the first car a at time t:

$$X_{a1}=V_a t+X_a \quad (2)$$

Where X_a is the coordinate of the first car at the start of time (not important).
As for the moment: t +1

$$X_{a2} = V_a (t+1) + X_a$$
$$X_{a2}=V_a t+V_a+X_a \quad (3)$$

For the second car b at time t:

$$X_{b1}=V_b t+X_b \quad (4)$$

Where X_b is the coordinate of the second car at the start of time (not important and will disappear).
As for the moment: t +1

$$X_{b2}=V_b (t+1)+X_b$$
$$X_{b2}=V_b t+V_b+X_b \quad (5)$$

Subtracting (2) from (4), we get:

$$X_{b1}-X_{a1}=V_b t-V_a t+X_b-X_a \quad (6)$$

Subtracting (3) from (5), we get:

$$X_{b2}-X_{a2}=V_b t-V_a t+V_b-V_a +X_b-X_a \quad (7)$$

Substituting (6) into (7), we get:

$$X_{b2}-X_{a2}=X_{b1}-X_{a1}+V_b-V_a \quad (8)$$

And we can put an absolute value on the result as the distance difference between the two cars if we don't care about the sign of the distance difference.
Now we will derive four equations from relation (8) that express the direction of the compounds:
We calculate the four general equations that determine the direction of the two vehicles, which are as follows:

First: the two vehicles go one way

$$X_{b2}-X_{a2}=|(X_{b1}-X_{a1})-|(V_a-V_b)|| \quad (9)$$
$$X_{b2}-X_{a2}=(X_{b1}-X_{a1})+|(V_a-V_b)| \quad (10)$$

Second: The two vehicles are in different directions

$$X_{b2}-X_{a2}=|(X_{b1}-X_{a1})-(V_a+V_b)| \quad (11)$$
$$X_{b2}-X_{a2}=(X_{b1}-X_{a1})+(V_a+V_b) \quad (12)$$

where:
$X_{b2}-X_{a2}$ The distance difference between the two vehicles at t+1.
$(X_{b1}-X_{a1})$ The distance difference between the two vehicles at time t.
Suppose we have two vehicles a and b as shown in Figure (8) the speed of the first vehicle $\boldsymbol{Va}$ = 10 m/s and the speed of the second vehicle $\boldsymbol{Vb}$ = 15 m/s

The vehicle is traveling horizontally on one axis (X axis).
Let the position of the first component $\boldsymbol{Xa}$ = 2 and the position of the second component $\boldsymbol{Xb}$ = 10
So the distance difference between the two vehicles at time t is $\boldsymbol{Xb1}-\boldsymbol{Xa1}$ = 8
By applying the values, the equations become as follows:
$X_{b2}-X_{a2}$ = | 8- (10 + 15) | =17
$X_{b2}-X_{a2}$ = | 8- (| 10-15 |) | = 3
$X_{b2}-X_{a2}$ = 8 + (10 + 15) = 33
$X_{b2}-X_{a2}$ = 8+ (|10-15 |) = 13
Now, after calculating the four equations, we calculate the distance between the two vehicles depending on the signal strength between them, and we compare the value resulting from calculating the distance with the values resulting from the four equations, and according to the value corresponding to the equation number, we determine whether we send the message or not?
Figure 4 show the direction of vehicle and its speed

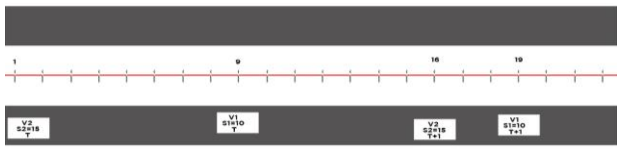

Fig -4 Vehicle direction and distance between them

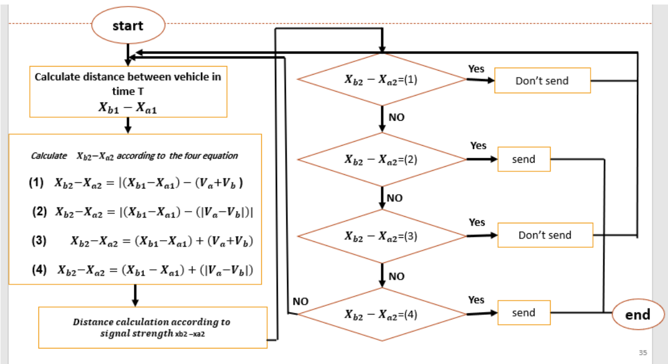

Fig - 5 Mathematical model flowchart

6.2. using the LAR routing protocol :

It is a protocol based on location information through GPS , so we will take advantage of this information to determine the direction of the nodes, and therefore, before the node sends data, it will determine the direction of the node; If it is in the same direction as the sender, it will send data and establish a connection, and if it is in the opposite direction, it will not send any data, as the connection will be interrupted due to the distance between the two vehicles. In this case, there will be a significant reduction in the number of data transmitted within the network, and thus the connection will be established for a very long time [13].

7. Results and discussion:

Tools and programs for wireless networks in general and vehicle networks in particular within a simulated environment based on the map of Aleppo, the University Square area, and these tools are:

1- OpenStreetMap _ It is a tool that converts any map into XML files to implement the required simulation [14].

2- SUMO: It is a program for vehicle networks based on creating a special network to implement simulations based on the map that was exported from the previous program [15].

3- NS2: It is the famous simulation program for wireless networks, which is based on establishing connections between nodes and implementing the proposed algorithm [16].

The simulation was built based on the parameters shown in the following Table (1):.

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

The algorithm will be simulated in two phases. The first phase will apply the aforementioned mathematical model to determine the vehicle's direction and discuss and compare the results. In the second phase, we will apply the LAR protocol to determine the vehicle's direction and analyze the results.

7.1. Results of applying the mathematical model:

7.1.1 End To End 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.

From chart (1) we notice an improvement in the delay time compared to the basic adaptive algorithm for a variable number of vehicles ranging from 20 to 100 vehicles in the simulation area.

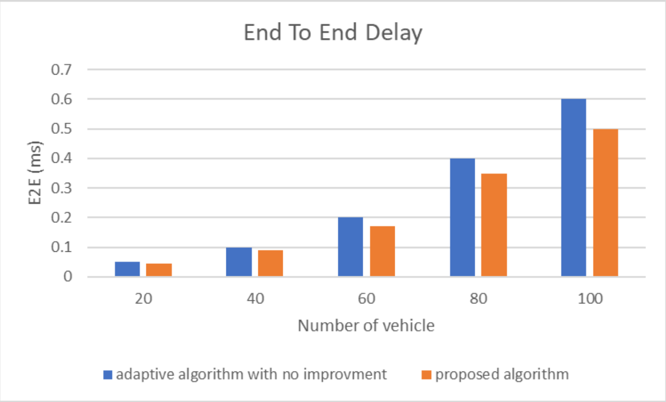

Chart -1: End To End Delay

7.1.2. 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 PDR.

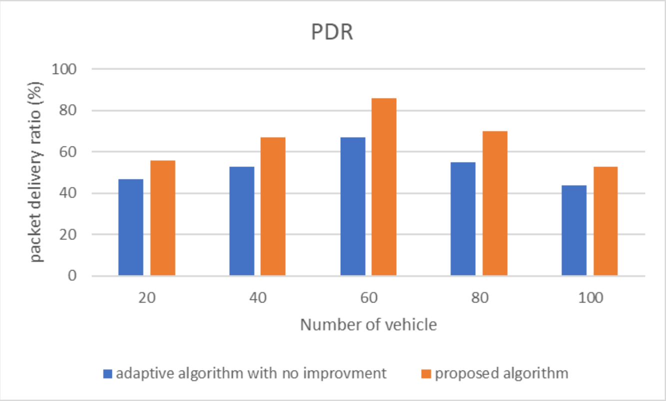

Chart -2: Packet Delivery Ratio

7.1.3. 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 vehicles. According to the results in Chart-3, we notice an improvement in throughput

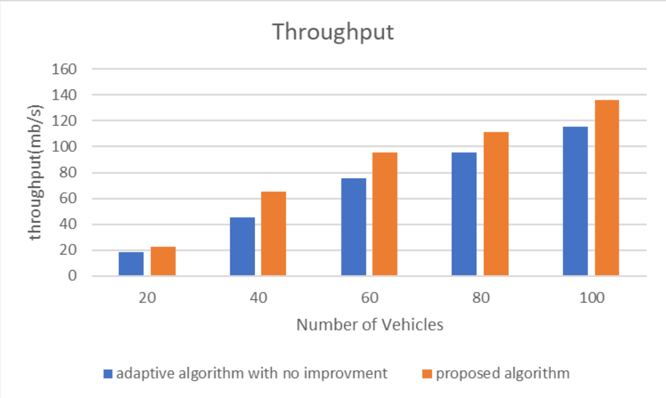

Chart -2: Throughput

7.2. Results of applying LAR protocol

We re-tested the proposed algorithm within the LAR protocol, and we noticed an improvement in the delay time, which in turn was reflected in improved throughput and improved data access rate compared to the improved algorithm within the basic protocol in the emulator, as shown in the following charts:

7.2.1 End to End Delay

chart (4) shows the results of the time delay values for the arrival of BSM messages between vehicles according to the proposed algorithm based on the LAR protocol. Comparison with the basic algorithm and the two algorithms in [5] and [7].

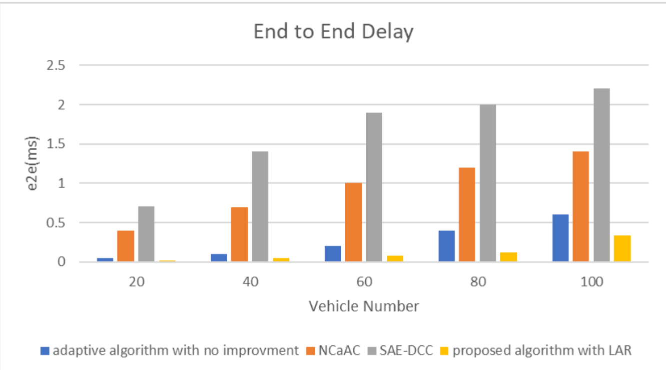

Chart -4: End to End Delay

7.2.2. Packet Delivery Ratio (PDR)

Chart (5) shows the results of the analysis of the ratio of packets between vehicles according to the proposed algorithm based on the LAR protocol Comparison with the basic algorithm and the two algorithms in [5] and [7].

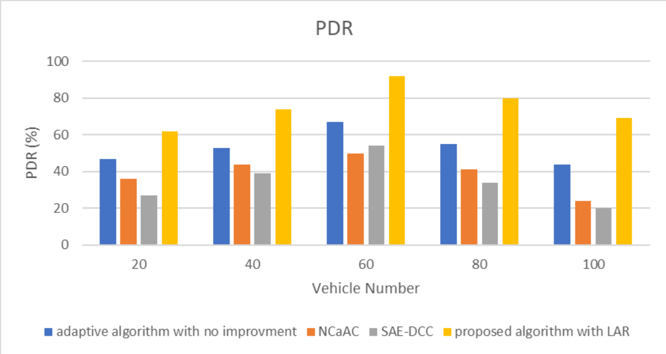

Chart -5: Packet Delivery Ratio

7.2.3. Throughput

Chart (6) shows the results of the throughput analysis according to the adaptive algorithm and the optimized algorithm according to the proposed algorithm based on the LAR protocol. Comparison with the basic algorithm and the two algorithms in [5] and [7].

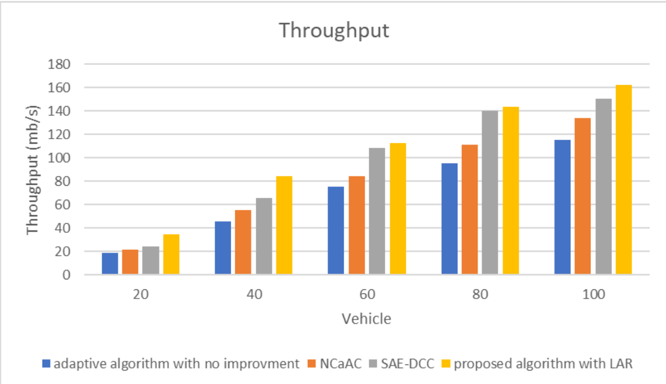

Chart -6: Throughput

From the above, we note a significant improvement in the results compared to both the basic algorithm and the two algorithms in previous studies, but we must mention some notes on the results:

With regard to the end-to-end delay, we note the superiority of the proposed algorithm, but we also note the increase in time with the increase in the number of vehicles, for the following reasons:

1- The increase in the volume of traffic within the studied area, and thus the delay in data transmission between vehicles

2- Increasing the number of hops that the banners must jump through to reach the receiving vehicle, and the higher the number of hops, the greater the delay

3- Increasing the number of vehicles within the network requires a stronger and larger infrastructure to be able to deal with the volume of data and the large number of vehicles. This infrastructure may need updates and development to be able to deal with the volume of data and the increasing number of vehicles.

As for the PDR packet delivery ratio, we also note the superiority of the proposed algorithm, and the ratio gradually increases with the increase in the number of vehicles to a certain number of vehicles, then the ratio decreases when a relatively large number of vehicles is reached.

The reason for increasing the ratio when reaching a certain number of vehicles is due to improving the quality of communication between vehicles and increasing the available bandwidth within the network, as well as to the availability of energy. With an increase in the number of vehicles, energy use can be reduced and the power of sending messages can be reduced, which leads to an increase in the rate of packet delivery.

As for the reason for the low percentage when reaching a relatively large number of vehicles within the network, it is due to the following reasons

1- Increased signal interference and radio wave interference, and this affects the quality of communication and increases the number of errors in reception, which leads to a decrease in the success rate of reception

2- Increased traffic volume, this can cause traffic jams and data interference between vehicles

3- Unavailability of energy As the number of vehicles in the network increases, energy use increases, and energy may become limited in some vehicles

Finally, with regard to productivity, we note the superiority of the proposed algorithm over the basic algorithm. We notice an increase in the productivity rate with the increase in the number of vehicles, due to the following reasons:

1- Reducing the distance between vehicles: The greater the number of vehicles in the network, the less the distance between them, which leads to higher signal strength and faster communication speeds between vehicles, and thus an increase in throughput.

2- Increasing route options: When the number of vehicles increases, the number of lanes available between any two vehicles increases, which contributes to improving route selection algorithms and choosing the optimal route in terms of performance and thus increasing productivity

8. Conclusion

Through the results that appeared with us, we conclude that if messages are not sent to vehicles traveling in the opposite direction, we notice an improvement in the measured parameters, and this in turn leads to an improvement in the performance of vehicle networks and thus an improvement in safety applications and an increase in the safety and security of passengers.

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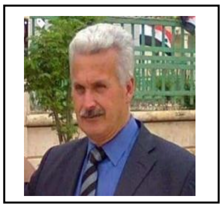

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