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RESEARCH PAPER

A comprehensive survey on congestion control techniques and the research challenges on VANET

Marwan Aziz Mohammed[1] , Shareef M. Shareef[1], Kayhan Zrar Ghafoor[1]

[1] Department of Software Engineering, College of Engineering, University of Salahaddin, Erbil, Kurdistan Region, Iraq

A B S T R A C T:

The nature of vehicular mobility and high speed of vehicular ad hoc network (VANET) with dynamic change in the network topology let the vehicular remain as one of the most challenging problems in vehicular-to-vehicular (V2V) communications. Information dissemination is the major problem in VANET with a fixed bandwidth which is causing congestion on the resources, such as channels and affects the performance of the important application, especially when the emergency or secure transmission of messages is exchanged between the vehicles-to-vehicles communication. To mitigate these problems and introduce a safe vehicular environment in urban and highway, congestion detection and control has been considered and with various strategies and techniques which is take the attention of researchers in VANET. In our survey we mentioned recent techniques and approaches which is used in congestion detection and control and applied different matrices and parameters which is used to evaluate these approaches. In addition, the study also explained the limitation and problems that face the current congestion detection and control schemes, finally we present various solution approach and future expectations in vehicular communication.

KEY WORDS: Congestion control technique, congestion detection technique, Connected vehicles, V2V, VANET.
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* **Corresponding Author:**
Marwan Aziz Mohammed
E-mail: Marwan.aziz@su.edu.krd
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NOMENCLATURE

ACRONYMS

BGR	beacon Generation Rate
MD-DCC	Message-rate and Data-rate Decentralized congestion control
3,4,5G	Third, Fourth, Fifth Generation
AC3	Adaptive transmit power Cooperative Congestion Control
AODV	Ad-hoc on-demand distance vector
BEAT	beacon inter-reception-time Ensured Adaptive Transmission
CABS	Context Awareness Beacon Scheduling
CBR	channel busy Ratio
MAC	Medium Access Control
MANET	mobile Ad-hoc Network
MBL	Maximum Beaconing Load
MEC	mobile edge computing
MORS	Multi-objective Overhead Routing Scheme
MOTabu	Multi-Objective Tabu
MPC	Multi-metric tx-power control protocol
NCaAC	Network Coding Admission Control
NCaAC	Network coding aware admission control

CBT	channel busy Time	OFDM	Orthogonal Frequency Division Multiple Access
CCH	control channel	PDR	packet delivery ratio
CLB	cooperative load balancing	PRR	probability of reception rate
CPRC	Combined power and rate control	PULSAR	Periodically updated load sensitive adaptive rate control
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance	QoS	Quality of Service
CSMA/CA	Carrier-sense multiple access with collision avoidance	QOS	Quality of service
D2D	device to Device	RSU	road side unit
DD-FPAV	dynamic Distributed-Fair Transmits Power adjustment for VANET	SBAPC	Speed Based Adaptive Power Control
DSRC	dedicated short range Communication	SCH	service Channel
EDCA	Enhanced Distributed Channel Access	SPAV	Segment-based power utilization for vehicular communication for VANET.
EEADP	Effective and efficient adaptive probabilistic data dissemination protocol	TDLTE	Time division long-term evolution
EMBARC	Error Model Based Adaptive Rate Control	TPRC	Joint transmission power rate control
eNB	evolved Node B	UE	user equipment
EPC	evolved packet core	UMDD	unicast multi-hope data dissemination
E-UTRAN	evolved universal terrestrial radio access network	V2I	vehicle-to-Infrastructure
FCC	federal Communication Commission	V2V	vehicle-to-Vehicle
FDCC	Fully Distributed congestion control approach	VDBPC	Vehicle density-based power control
GPS	Global positioning System	WiMAX	Worldwide Interoperability for Microwave Access
IDP	Inter-packet Delay	Zigbee	Zonal Intercommunication Global-standard
IEEE	Institute of Electrical and Electronics Engineers		
IRT	Inter-reception Time		
ITS	intelligent Transport System		
LIMERIC	liner integrated message rate control		
LTE	long Term Evolution		

1.INTRODUCTION:

Nowadays VANET is a significant component of Intelligent Transport System (ITS) that attracted many researchers in the field of automotive communication and academia. One of the technologies that support (ITS) is Dedicated Short Range Communication (DSRC) to provide road safety and mitigate car accidents in Urban and highway. These services can make the drivers feel more comfortable and drive safely than before. There are many applications that provide an efficient vehicle to vehicle communication such as road safety programs, general services, and messaging which hold important information, like weather forecasting, and gaming program, which is related to transportation utility. VANET is a connected vehicle and it considered as a special kind of Mobile Ad-Hoc Network's (MANET).

VANET have different architectures for vehicular communication which is Vehicle-To-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and hybrid V2V/V2I. In (V2V) nodes can connect to each other directly for exchanging information and awareness without any intermediate devices, while in (V2I) the communication occurs through a third device or point on the roads which is roadside unit (RSU). V2V/V2I vehicles can communicate with the roadside unit (RSU) through single hope or multi-hope which is depending on the V2V.

Federal Communication Commission (FCC) has approved the Dedicated Short-Range Communication (DSRC) standard for V2V/V2I with seven non-overlapping channels, six Channels for Service (SCH) and one for the control channel (CCH) (Feukeu, and Zuva, 2020). DSRC support up to 75 MHz as an overall license with band ranged from 5850 to 5925 MHz for VANET with different 10 MHz between the channels. The figure 1 below shows the DSRC with supporting channels and its septum (Pattanayak et al., 2020)

Control channel is used to broadcast messages about the road conditions to all the nodes in the transmission area, service channels are used to transmit, share personal and entertainment information to the neighbour vehicles.

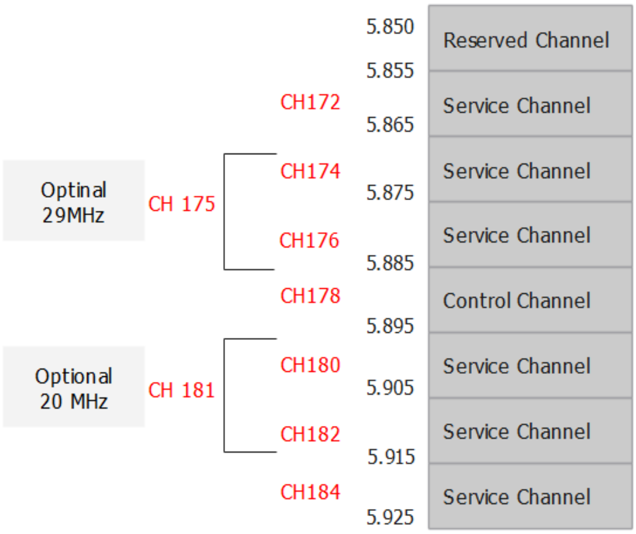

Figure 1: DSRC communication channel

There are two types of messages available in VANET Safety messages and non-safety messages (TORRENT-MORENO et al., 2009). Safety messages are used by safety applications in VANET. Periodic messages are broadcasted between the connected vehicles and share sensitive data such as speed, position and the direction of the vehicular network. However, emergency notification is propagated when the car crash or car accidents occurs on the roads. Safety messages (Karagiannis et al., 2011) are used to mitigate the accidents that are happens on the roads, in addition, to reducing traffic jam which ultimately enhances the safety of vehicular communication. High mobility and dynamic changing of the vehicle's network on the roads is very critical which leads to the inconvenience of drivers and not reacting properly in many situations. Safety messages which are considered to alarm the drivers about the danger cases for example road accidents and so on.

Emergency messages were broadcasted to the surrounded vehicles in the transmission area of communication to notify the drivers about the road conditions, resulting in reducing their moving speeds in order to be on the safe side before reaching to the site of accident. Moreover, the probability of accident occurrence and traffic jams on the roads in urban and highway environment increased especially when the number of vehicular nodes is high (Guerrero-Ibáñez et al., 2013). To improve the efficiency of vehicular communication and increase the awareness of the drivers through the use of safety applications that alarms each other about an emergency case. These applications have many advantages such as consuming time and fuel consumption by guiding to the shortest paths (Liu et al., 2005). non-safety messages in VANET are giving information about the traffic condition to comfort vehicular drivers to select the shortest path (Hartenstein et al., 2009). non-safety applications also support other activities such as sharing the files and information, entertainment applications among the vehicle drivers and so on (Nassar et al., 2012) (Kaur, 2012)

DSRC uses the Wireless Access in Vehicular Environments (WAVE) for V2V and V2I communication. WAVE consist of bund of standards which is approved by IEEE 802.11p for Physical-layer and Medium Access Control (MAC) protocols, and other definition like IEEE-1609.1 till IEEE-1609.4 for the protocols of above layer (Qin, 2020). In 1999 the federal communication commission (FCC) has set aside the DSCR to increase safety. Figure 2 shows the IEEE architecture and WAVE standard. As mentioned, the IEEE structure consists of four important parts in vehicular communication which is IEEE 1609.1 which is represent the network resource manager, IEEE 1609.2 represent the security which is applied to all layers, IEEE 1609.3represent the transport and routing layers and IEEE 1609.4 represent the MAC and Physical connectivity.

Congestion in VANET is a very big challenge and any researchers are working on this issue to reduce the occurrence of congestion in vehicular communication. Congestion may happen due to the delivery of messages that are swapped between the connected vehicles in a network, which causes an efficiency decrease in the network performance in terms of delay, packet loss and mitigating the activity of the network in general. High mobility, network density and dynamic

change of the network topology also shrinkage of channels which is causing the spectrum of channels not adequate to deliver the information that is created by messages. Figure 3 shows connected vehicles in both V2V and V2I, and indicate that the congestion occurs if the number of nodes increases at the roadside unit RSU and between the vehicles, consequently the network throughput will decrease (Yung at al., 2020).

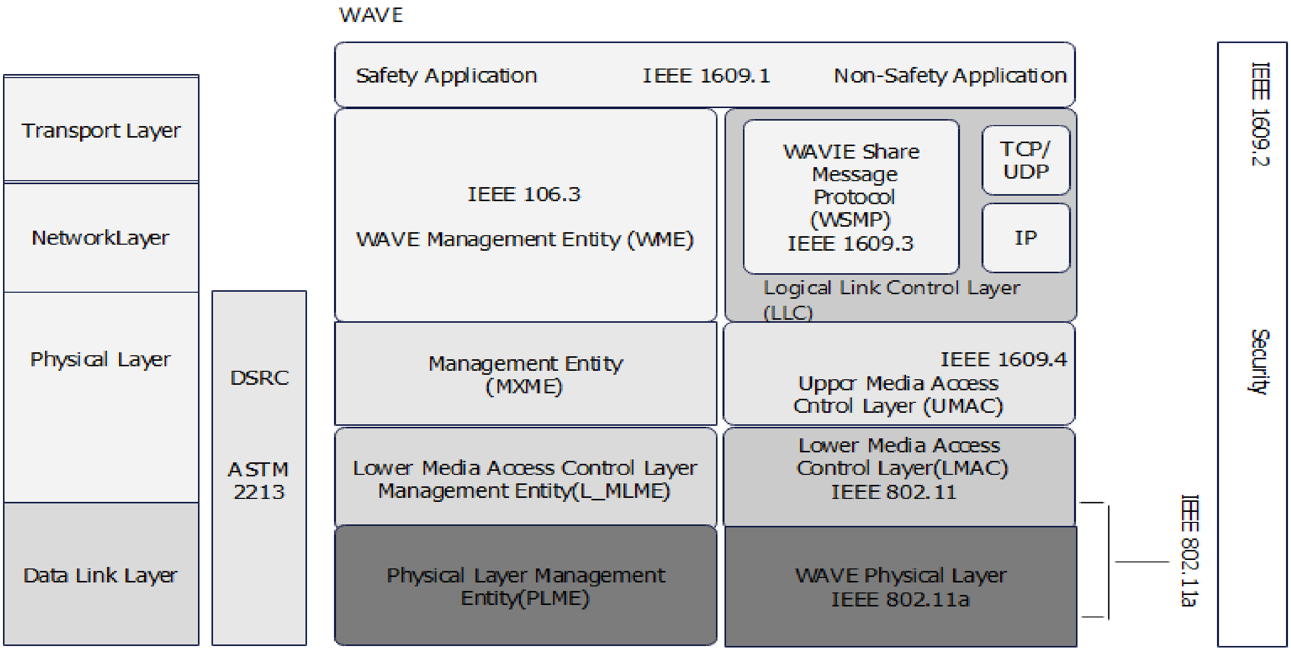

Figure 2: WAVE, IEEE-1609, IEEE-802.11p With Network Layers.

The structure of the survey paper is arranged as the following: Part 2 shows the related study in both congestion detection and control approaches. Part 3 and 4 explain in details congestion detection and control mechanism respectively. Part 5 concentrating on the limitation of exist congestion detection and control schemes and shows future research directions.

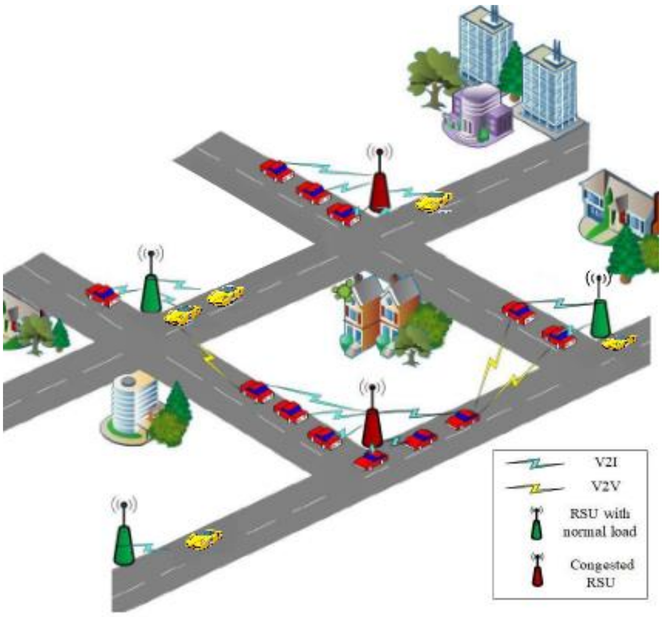

Figure 3: VANET Network (V2V, V2I)

2.Related Works

In vehicular communication, the information exchanged among the connected vehicles within the permitted area of transmission. We will discuss different types of messages that are available in vehicular ad hoc network VANET these messages are called Data, Event-Driven and Beacon messages. In critical situations such as accidents on the road, vehicles crashing or traffic congestion, these messages should reach the connected vehicles in the region of communication within a specific time interval. Delay is considered a critical parameter in VANET, these messages must deliver to the destination with minimum delay. Messages carry time crucial information which is very important, while beacon messages are called periodic update messages, which is propagated periodically through the connected nodes to forward and receive the notification regarding the vehicular network (Bhatia, 2020).

Recently, many researchers those interested in congestion detection and control suggest various approaches which are monitor, detect, and reduce congestion in the vehicular network. For enhancing the quality of service and have better use of network resource management in VANET. Different algorithms for VANET congestion control and congestion detection have been proposed. These methods can be categorized into two model of working, those detect the congestion after occurrence of congestion and those that detect the congestion before it happens. In this part, we will discuss the effect of some parameters such as, delay, available bandwidth, channel usage on the network performance of the existing congestion control and detect in the connected network in both vehicular-to-vehicular and vehicular-to-Infrastructure, and discussing the integration of available congestion control strategies with modern communication technologies.

2.1 Effect of Parameters on the Performance of Congestion Control Technique

Due to dynamic changes in the network topology of VANET, the probability of vehicular ad hoc network availability is unstable. Information transmission and path selection must be done within a limited period of time, because any change in the value of the metrics will affect the network efficiency, duration should be considered in order to reduce the congestion in the vehicular communication (Balasubramanian et al.,2020) (Aloqaily et al., 2018). We will show the existing congestion control based on some metrics which has been recognized for evaluating the execution of VANET congestion control method (Joseph et al.,2018). In the next section we will explain common parameters that has significant effect on vehicular network.

2.1.1 Packet Delay and Throughput P4

Delay is considered as sensitive parameter in vehicular network. Inter-packet Delay (IDP) is counted as the time between the successive packets, and Inter-reception delay (IRT) is receiving period between two subsequent or consecutive sender recipient pairs. IDP is known as the common delay between the packets which can be picked by the mobile vehicles in the region. IDP and IRT are considered as the main metrics for determining the efficacy of the congestion control technique in vehicular communication. Time value in a wireless network in general and in VANET especially is very critical when the safety messages are exchanged between the vehicles. The minimum inter-packet delay led to minimize congestion in the network, in addition to other parameters, such as network density which has a significant impact on the delay of packet transmission (Chour et al., 2017). Throughput is known as the number of packets that are transmit by the sender vehicles and reached the destination if the collision occurred it will cause arriving minimum packets to the destination and the throughput will be decreased. The nature of the vehicular network is special and not stable because of the dynamic change of the network topology. Vehicles need time to discover the neighbors' nodes and it's required to minimize the time of route discovery in order to reduce the latency.

2.1.2 Packet Delivery Ratio P4

PDR has significant impact on the performance of vehicular Ad-hoc network. PDR counted as critical metrics in VANET to determine the probability of congestion occurrence in a vehicular network (Spaho et al., 2012). Delivery ratio-based mechanism is dynamically tuning the transmission rate or packet generation rate to control the congestion in the networks. Increasing the number of packets rate indicating good connectivity of vehicular networks in the propagation range is led to maximize the performance of vehicular Ad hoc networks. Packet delivery ratio can be measured through the values (0 to 1), if we received maximum value of PDR that means maximum packets has been received by the destination vehicles. In another way, if the value of PDR is equal to 1 mean all the packets received by the destination. recent information which is received by safety applications is necessary to determine the situation of each neighbors' vehicles, in order to work efficiently and have perfect network connectivity.

(Zhang et al.,2014) Rate of delivering data is measured by the ratio of delivering the broadcast message to the connected nodes in the transmission range. Reliability of transmitting the packets defined as the average number of nodes that are receiving the notification which is led to maximize the beaconing delivery in the vehicular network especially when the number of the connected vehicular is reached a higher level, results bandwidth consumption and consequently congestion happen in the control channel. Minimum transmission time and maximum packet delivery are essential to have an optimal VANET connection (Elias et al., 2019).

2.1.3 Channel Busy Ratio.

To enhance the packet delivery ratio which in turn will enhance the performance of the connected network, CBR is considered (Falah et al., 2011). This parameter has a significant impact on the power control schema and rate control schema at the MAC level. Sometimes CBR is equivalent to Channel-busy time CBT which is the time when the channels are sensed as busy, and the all-observation time. Channel load or channel busy is depending on the number of messages that are generated and the total number of nodes in the area of transmission. Channel busy ratio has a considerable impact on the power control and rate control which is the response of the VANET network against the network traffic. CBR can be used as one of the important metrics to measure the performance of the broadcast throughput which is called Information Dissemination Rate (IDR) of a vehicular ad-hoc network and the channel busy ratio for all different combine between rate, power, or traffic density. IDR also can be found as number of packets deliver for the specific period of time from a vehicle to its surrounded nodes for a limited distance. These approaches are used to maintain the busy channel ratio BCR to get a better level so that the probability of getting the network congestion will be very less (Elias et al., 2019).

2.1.4 Other Parameters

There are different metrics that effect the performance of network, in term of packet delivery ratio, throughput, delay and channel busy ratio parameters such as high speed of vehicular, dynamic change of the topology, the density of the vehicular density and location which has a significant effect on the network congestion in different transmission ranges of vehicles (Mylonas et al., 2015).

3.Congestion Detection Techniques

Congestion detection methods in the vehicular networks is very necessary for wireless communication, especially in VANET's application and services. Unstable network topology, high velocity of connecting nodes and network density cause congestion (Singh et al., 2018). To avoid congestion, we need to have up to date information about the connected links that are congested at a specific period of time. As mentioned before when congestion happen in the VANET, immediately the congestion control should be applied to the area of congestion in order to mitigate the congestion to avoid road jamming and vehicular accident on the roads (Ahmednagar et al., 2019). There are many techniques that are available for congestion detection in vehicular communication based on some matrices such as:

To detect the congestion at different layers of the vehicular network cross-layer mechanism is considered. Matrices based congestion detection mechanism such as usage of channel, occupation of channel period and a number of messages that are available in the waiting list (queue). The dynamic and distributed mechanism is followed in VANET. Position base mechanisms for congestion detection, which is dependent on the distance and network connectivity of the path toward to the destination, will determine the route of intersection for congestion control by selecting the best routing protocol to reach the destination within the shortest path (Cheng et al., 2019). Table 1 shows the congestion detection methods.

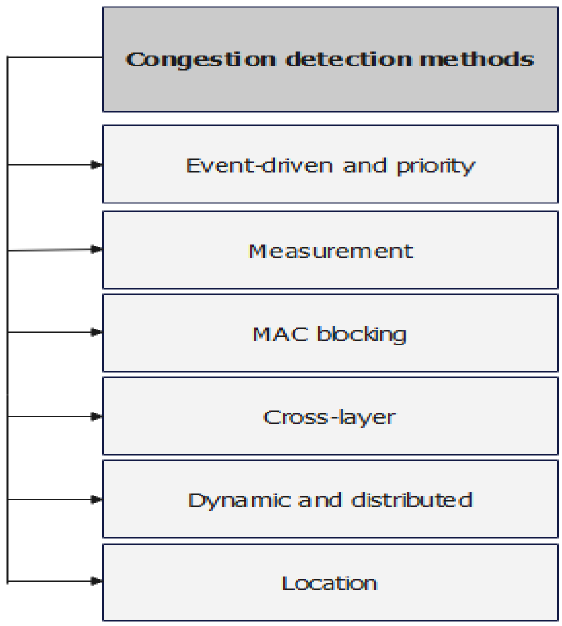

Figure 4: Congestion detection technique**.**

3.1 Event-driven approach for congestion detection

Event-driven messages are used for congestion detection when road jamming, car crashing occurred on the road, then the Event-driven messages are created, which is result in starting of the congestion detection approach.

Transmitting beacon periodically has been proposed by (Biswas and Samanta, 2020) to transmit the information. Delivering rate of safety messages is based on the safety of the vehicular connection which is different from the ratio of the control algorithm. Due to the limited period of the control channel (CCH), and link busy, counted as the main issue for dropping the messages in the connected network of VANET.

In the VANET network, when the dropping of packets or packet lost is bigger than the threshold value, it will be sensed by the congestion detection algorithm and determine the vehicular that caused the congestion. There are some techniques used to mitigate the route fading in the vehicular communication by sending the packets again through one of the available vehicles based on the distance metric mechanism.

(Bouassida and Shawky, 2018) consider the characteristic of dynamic priority-based technique for congestion control selection. Control and service channel delivered messages to the network. Congestion control detects the congestion in the network through the number of packets that are sent and received on the networks. The delay parameter for those messages that have high precedence is less compared to those that have low precedence. Priority of messages has a significant effect on network congestion, in addition to routing effects especially in a crowded area of vehicles. (Taherkhani and Pierre, 2020) suggests another technique used for congestion detection for VANET based on the dynamic and distributed methods. This mechanism has the capability to detect congestion. Congestion can be discovered by sensing the channel usage level and checking its value with the threshold value. Thus, the channel will be free of congestion when the number of nodes raised in the area. However, because of the threshold value, network high density will affect the vehicular network in term of packet loss in crowded area (Fuekeu and Zuva, 2017).

(Manjoro et al., 2016) proposed data mining algorithm to tuning the threshold value in the VANET network is very important when this value is compared with the channel occupation level by sensing the link if it is exceeded the congestion will be detected. Thus, transmission area increased in density network and the channel will not congested. However, packets will drop because of the high density of vehicles and the setting of thresholds value. (Taherkhani and Pierre, 2016) proposed some congestion detection techniques, depending on the priorities and organize the messages schedule in VANET .in VANET static, dynamic, and message size will determine the priorities that given to the message, before the message is sent to the link channel the control and service channel should be organized. Message header has many values, priority added to the message header, delay is increased because of needed time to rearrange the message base on message priority and schedule.

3.2 Measurement approach for congestion detection

This approach of congestion detection in vehicular communication depends on some parameters such as channel capacity and channel usage. To know that the channel has been congested, they will depend on the comparison between the mentioned parameters with the specified value which is already determined to decide whether the channel is congested or not. (Zeroual et al., 2019) (Shi et al., 2019) proposed a mechanism for detecting the congestion in the connected vehicular through comparing the threshold with the usage of the channel at the specific period of time. If the channel occupation is baggier than the threshold value, then the channel congestion will be confirmed and advertised to all vehicular in the transmission range. (He et al., 2010) shows that congestion can be detected based on the DSRC. Most of the messages that are travelled on the network will be dropped when the channel is congested. (Taherkhani and Pierre, 2015) suggested using of meta-heuristic algorithm to notify the congestion detection, two parameters are considered for congestion detection, which is the detection section and measurement section. (Araújoet al., 2014) Channel usage and the number of messages in the waiting list are checked by the measurement section. When the using channel reached above 70, it indicates congestion and the detection section will be notified and send this information to all vehicles. The benefits of this method are low load and minimum packet dropping. However, the delay increased when the number of transmitted messages increased which is lead to congestion detection in the network (**Liu** and Jaekel, 2019) and (**Gulik** et al., 2019).

Table 1: Congestion detection methods base on different metrics

Algorithm Name	Detection Technique	Type of Notification	Challenges
Adaptive Beacon Generation Rate (ABGR) congestion control (Sousa et al., 2020)	Event-driven messages	Beacon message	Delay and packet dropping
Dynamic strategies (Taherkhani and Pierre, 2016)	Measurement-based	Beacon message	Network overhead will increase
Cross-layer technique (Jabbarpour et al., 2014)	Event-driven messages	Safety message	High delay
Distributed approach (Darus and Bakar, 2011).	Event-driven messages	Beacon message	Channel load
Contention-Based approach (Bellache et al, 2017)	MAC blocking detection	Beacon message	High delay to check the overhead
Cooperation Vehicular Traffic-congestion Identification and Minimization (CARTIM) (Araújoet al., 2014)	Measurement-based	Beacon message	High packet loss
Decentralized methods (Sharma et al.,2019)	MAC blocking detection	Safety message	Maximum delay and packet loss
Data mining methods (Manjoro et al., 2016)	Event-driven messages	Beacon message	Channel congestion
Dynamic distributed methods (Zhang and Valaee, 2016).	MAC blocking detection	Beacon message	High delay
Periodically Update Load-Sensitive Adaptive Rate control methods (PULSAR) (Liu and Jaekel, 2019)	Measurement based, Event-driven messages	Safety message	packet loss and jitter
DSRC considered for congestion control (Bansal and Kenney, 2013).	MAC blocking detection	Beacon message	Maximum delay
Location based approach [73] (Gulik et al., 2019)	Measurement-based	Safety message	packet loss and delay

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3.3 Media Access Control Blocking Approach for Congestion Detection

Media Access Control blocking approach used for congestion detection on the channel and links which is depend on the transmitted ratio of beacon and the packets that are travelled on the VANET network (Li et al., 2019). (Bellache et al, 2017) proposed that sending beacons periodically meaning for each specific period of time will resend called Contention-Based approach to detect the congestion. In order to resend the messages, the mechanism depends on the channel busy rate to limit the number of retransmission and will continue with resending, stopped when it reaches the predefined value (Sharma et al.,2019). Moreover, the contention-based approach will check the channel overhead to collect the information and determine the congested links.

(Willis et al.,2017) and (Rath et al.,2019) proposed a congestion detection approach that focus on the alteration, the transmission power should be fit with the transmission rate in order to mitigate the congestion. This schema checks the transmissions to fewer distance vehicles over transmissions to long distant vehicles. (Math et al.,2017) concentrate on the message count than depending on the specific value. This schema monitors the maximum number of messages that have been transmitted in the network (Bansal and Kenney, 2013).

(Chen et al.,2017) depended on the non-cooperating bargaining game for congestion detection strategies. The idea of this theory is by dividing vehicles network into groups, each group has a member and head. The group head deals with each member of the group to select the best combination of power transmission and messages generation for the member. This approach may cause delays because of negotiations and head selection (Zhang and Valaee, 2016).

3.4 Cross-layer approach for congestion detection

Delay is the critical parameter in wireless communication especially in VANET, because of the dynamic change of the vehicle's network. To guarantee receiving messages by vehicles neighbors to save the people's live and drivers, safety messages should reach with minimum delay. To implement this, high bandwidth should be available for vehicular communication (Jabbarpour et al., 2014). Cross-layer approach have two modules. The first one is responsible to detection of event-driven messages when an unexpected event or emergency happens this model will notify the main center. The second model will sense and advertise the channel load. The are many parameters the sensing will base on, for example, packet delivery ratio, transmitting time and so on to determine the congestion (Zhang et al., 2020). The threshold value is determined for channel bandwidth utilization. The figure below shows the procedure of cross-layer technique in congestion detection.

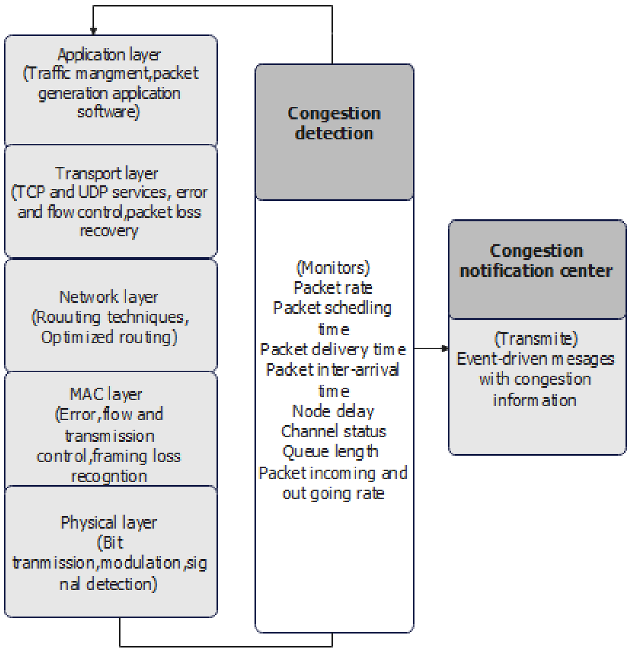

Figure 5: Cross-layer Procedure in Congestion Detection model.

3.5 Dynamic and Distributed Approach for Congestion Detection

Dynamic and distributed used frequently in vehicular network which has significant impact on the network performance in both urban and highway environment. This mechanism also called MOTabu used for congestion detection control. The strength point of this approach is detecting the congestion base on the value of some parameters through monitoring the available channel such as, level of channel usage, occupancy time of the channel and the capacity of queue in term of total number of messages.

For measuring the performance of MOTabu some metrics has been considered for instance, delay of transmitting the messages, total number of packet that loss, throughput, packet dropped during the delivering, and number of retransmissions. The occurrence of congestion is detected through measuring the value of mentioned parameters and scan the connected links (Darus and Bakar, 2011).

The channel usage percentage of the vehicular communication is checked periodically and compared with the threshold value (Cho et al., 2020). Threshold number is counted as the usage of current channel in wireless communication. If the exists usage of the channel bigger greater than the threshold, then the channel will list as congested link, which is led to implementing of the congestion control mechanism to prevent the congestion. If the congestion is detected, congestion control algorithm is applied to mitigate the congestion. A tabular method is running along with exists algorithm. This algorithm is considered to minimize the occurrence of congestion on the channels.

3.6 Position-based Approach for Congestion Detection

In VANET one of the challenges is the message routing among the vehicles or roadside unit points. Routing between the vehicles is very critical especially when the number of vehicles increases which may cause disconnection of the link between the vehicles (Babaghayou and Labraoui, 2019). In congested situation, channel usage increases which leads to frequently congestion occurrence. Position based congestion detection which is mentioned the congestion link, vehicles and channel depending on the connected links (Aravindhan et al., 2019).

This technique considering the path that is determined based on the number of intersections which is determined through some techniques (Nebbou et al., 2017). When the congestion occurs on the channel the roadside unit RSU propagate the notification about the congested channel and saved the path link to the congested area which is a set of intersection, then is shared with neighbor vehicles. The disadvantage of this approach is the high delay and communication overhead. This approach needs high cooperation between the RSU to discover and transfer the congestion notification to the directly connected vehicles (Paranjothi et al., 2018).

In part 3, we have explained the recent technique that are considered in congestion detection techniques which are event-driven, priority, measurement, MAC blocking, cross-layer, dynamic, distributed, and location-based techniques, the cross-layer and location-based approaches preferred and frequently used by the researchers nowadays. During the work of cross-layer mechanism through monitoring all TCP/IP layers to detect network congestion and in each layer have its procedures. In contrast, location-based techniques give accurate details regarding the network and statistical analysis to detect congestion in the specific transmission range. Main controller, such as RSUs give an optimum route to all nodes in the communication range. Moreover, cross-layer and location-based techniques works efficiently especially in very high vehicle densities. Thus, the cross-layer and location-based algorithms are used to compared with all other congestion detection techniques. Some of the cross-layer and location-based congestion control techniques needed high cooperation among vehicles and therefore, incur high overheads and maximum delays in high vehicle density region. To eliminate these challenges, we have explained important strategies that perform well to detect the congestion in Section 3. In this part we will explain the approaches of congestion control in VANET.

4. Congestion Control Techniques

Vehicular Ad-Hoc network is a special type of wireless communication, which is pay the attention of many researchers and industries in field of wireless and communication to find the proper mechanism to solve the limitation and challenges. The demand for the VANET applications and services increased by the industries and car companies' day by day in both vehicles-to-vehicles V2V and vehicles to infrastructure V2I. Unstable topology and dynamic change of connected network of the vehicular network, transmitting the safety and emergency messages and the guarantee of receive these messages by the destination become big challenge in VANET. Quality of service (QOS) is very important in order to save the people live and during driving their car to reduce the car accident on urban and highway roads. Therefore, congestion is necessary to be controlled in VANET, especially in rush hours and in crowded area. For this reason, a lot of technique has been deployed and published in VANET to detect and control the congestion in vehicular network. During this study we will list these mechanisms and compare them in in term of different metrics and conditions environments.

To improve the network performance and guaranteed the efficient and maximize the performance of vehicular communication, the channel usability, bandwidth and some other parameters should be considered and utilized. To have a save environment of vehicular network on the roads, congestion control algorithm proposed. These algorithms should response to the event quickly and applying their mechanisms when it need. Response time is integrated strongly with congestion algorithms, some algorithm measured the time of replay by the applying Round-Trip

Time RTT algorithm for vehicular communication (Taherkhani and Pierre., 2012).

Congestion control mechanism in VANET can be divided into strategies, open-loop and closed-loops congestion control. Open-loop mechanisms prevents congestion to happen, and close-loop will control the congestion after detecting the congestion in VANET (Tanenbaum, 2014). The open-loop technique is following specific rules, for example retransmission of packets, determining the size of the windows, accepting and denying the packets, storing the packets that are arriving late, flow mechanism and acknowledgement to prevent the occurrence of congestion. The close-loop mechanisms are depending on the back pressure, choke data, implicit signaling, and explicit signaling.

Congestion control mechanisms in the vehicular networks can be categorized based on some function and parameters. Congestion control mechanism divided into three types which is proactive, reactive and hybrid, all of them tried to deny a restrict congestion control in VANETs.

In proactive model, the approaches aim to prevent the occurrence of congestion based on specific parameters such as the number of neighbor nodes, data creation style. These metrics will adjust to prevent the channel congestion to happen. This strategy defined as open-loop congestion control in VANET. The proactive technique calculated the channel load which is generated by the neighbor nodes to increase the performance of the application used in VANET. The proactive mechanism is preferable in VANET communication. Increasing the efficiency of vehicular communication is very important especially when the critical messages are propagated to the region of interest. This approach is required for controlling the congestion VANET, in order to propagate the safety messages which is primarily sent to the radio communication and threatened by channel congestion. To find out the ratio of channel loads through the connected vehicles, proactive algorithm generating a model for communication for mapping the energy that are require for transmission to the carrier sense. In proactive strategies, the delay factor is also estimated for channel load (Jabbarpour et al.,2014).

The reactive model, these strategies consider the acknowledgement that are received from the channel congestion conditions to decide when to conduct the congestion control mechanism, then to utilize the parameters that have significant effect on the transmission. Reactive mechanism can be categorized under the closed-loop congestion control that controls the congestion after it happen in vehicular communication. This approach is comparing the value of threshold with some parameters value like channel, waited packets in the queue and occupancy time of the channel. Reactive is periodically sensing the medium and calculating the value mentioned before to discover the congestion in the region. Transmission metrics have decreased a load of channel when the congestion happens in the channel in order to control the congestion. Reactive strategies minimize a load of the channel when it receives notification messages from the vehicles. These critical conditions will decrease the network performance and it’s mandatory to return back to connected network from these critical satiations by controlling the congestion in the network (Sepulcre et al., 2011).

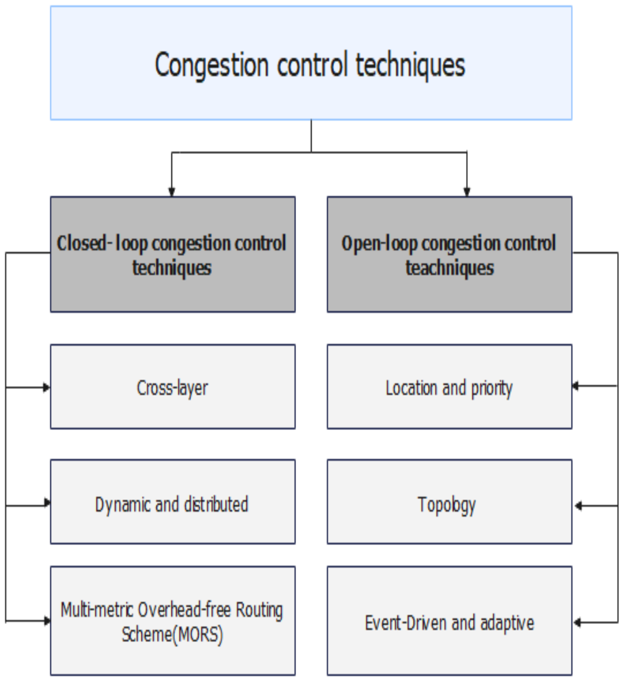

Figure 6: Congestion control technique.

The third kind of congestion control model in VANET is the hybrid methods. This approach used the good behaviors and procedure of both proactive and reactive and ignoring the unsatisfied functions. For example, this method working on the tuning the value of transmission power proactively and transmission rate reactively to mitigate and prevent the occurrence of congestion in vehicular communication **(**Jabbarpour et al.,2014)

Wireless network deals with congestion control in two methods, end-to-end and hop-by-hop model. In an end-to-end approach, the connecting is restricted between the sender and receiver only, which are not preferable for controlling the congestion in VANET, because the nodes which are in between are not counted and ignored such as collisions interference and the transmission issues. In the hope-to-hope model which is working opposite to end-to-end, here the intermediate node has a significant contribution in the congestion control process (Bouassida and Shawky, 2008). The hop-by-hop mechanism is preferable in congestion control in vehicular communication, because of dynamic change of network topology and other issues such as storage and computational ability. However, the hope-to-hope technique has some challenges, for instance overhead that is generated by this application that depends on hope to hope, and scalability problems. Due to the limitation which is mentioned before its necessary to suggest some techniques which is considering the feature of VANET like a dynamic change of network topology, high mobility of nodes, in addition to network density. In the next part, we will explain the available congestion control technique in VANETs based on the close and open loop techniques.

4.1 Closed-loop congestion control Techniques

In this category of congesting control in VANET, the congestion mechanism will work after the congestion is detected. Many techniques have been published using this category which is cross-layer technique, distributed technique, multi parameters overhead free routing.

4.1.1 Cross-layer Technique

Cross-layer method concentrates on how to keep the load on the channels when the congestion happens. In VANET the congestion control mechanism happens in all layers and it works as follows (Jabbarpour et al., 2014). In the physical layer which is the first layer in VANET for controlling the congestion, detecting by monitoring the channel through assigning some value to the channel. In the second layer MAC layer, in order to reduce the congestion, a priority number will be assigned to the packets. Packets with high priority will transmit and packets with low priority numbers are ignored. This technique led to mitigating the channel load. Many algorithms suggested to minimize the load of channels and reduce the congestion such as optimization, routing and machine learning algorithm. To minimize the load in the transport layer, User datagram Protocol is used instead of TCP. Finally, the application layer also uses some techniques to mitigate the congestion and load through some technique for instance, condition and application-based algorithms.

4.1.1.1 Channel load-based Congestion Control

This technique considers the threshold value to measure the loads on the available channel. Some algorithms have been used such as Dynamic Distributed Fair transmits Power Adjustment for VANET (DD-FPAV). This approach controls the transmission power and packet generation. The value of channel load is calculated depending on the road requirement and traffic condition. Traffic status in both high- and low-density environment will find based on the information that is received from beaconing messages and also event-driven messages which will be available in one of the message fields. The working mechanism of (DD-FPAV) procedure is to select the proper value for Maximum-Beaconing Load (MBL) and Beacon Generation Rate (BGR) to collect the information through these beacons. DD-FPAV algorithm also measures the energy for all vehicles in the transmission range and then chooses a value (Jabbarpour et al., 2014).

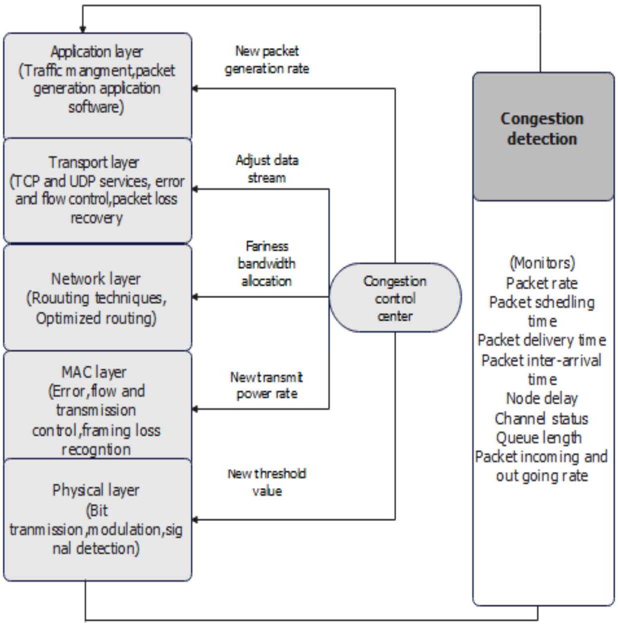

Figure 7: Cross-layer Procedure in congestion control**.**

4.1.1.2 Channel Busy Ratio (CBR)-based Congestion Control

Monitoring the channel busy ratio and channel busy time at some specific interval by vehicles is necessary, especially when the congestion is detected. Periodically updated load sensitive adaptive rate control (PULSAR) algorithm is applied when the value of channel busy ratio is bigger than the objective value. Congestion control is started in order to mitigate the congestion. PULSAR algorithm reduced the number of transmission base on the target value, the limitation with PULSAR is causes delay during the transmission because of comparing with objective value, which lead to power consumption **(**Tielert et al., 2011).

4.1.1.3 Message Rate and data Rate-based Congestion Control.

This technique considered in vehicular network to reduce congestion in vehicular communication. Message-rate and Data-rate Decentralized congestion control (MD-DCC) algorithm working to adjusting the data rate when the vehicles send the data at a different ratio to prevent the congestion, so the synchronization between the sender and receiver is still a huge problem. Vehicle density is another limitation for congestion, which requires a high rate need a maximum signal to Noise Ratio. MD-DCC always remains stable with beacon frequency by minimizing the data rate, in resulting reducing the congestion (Math et al.,2017).

4.1.2 Dynamic and Distributed Technique

The dynamic and Distributed approach used to control the congestion in VANET, which is considering some parameters such as packet loss and packet delay, throughput and transmission rate. In order to control the transmission of packets and packet rate in both safety and non-safety messages in VANET, this approach reduces the delay and jitter. Due to dynamic change of the network topology and high speed of network node with different mobility patterns, which still remains as the main challenges in VANET. This approach controls the congestion among connected vehicles. By rising of area of communication and transmission rate, results to increase the collision occurrence in the region. a Multi-Objective Tabu (MOTabu) segment-based power utilization for vehicles network (SPAV) algorithms are considered to distributed congestion control in VANET (Taherkhani and Pierre, 2015)**.**

4.1.2.1 Setting Transmission Range and Transmission Rate-based Congestion Control.

Tuning the transmission rate is one of the vital parameters to control the congestion in vehicular communication. Controlling the transmission range and rate can be classified under NP-hard and Meta-heuristic techniques. There are many algorithms and method following NP-hard and Meta-heuristic technique, MoTabu is one of the algorithms which is aims to tune to the best value for transmission range and rate with considering the delay and jitter to be at a minimum. Based on that optimum value the communication will transmit the data on the vehicle's environment.

The figure below shows the mechanism diagram working of MoTabu memory management for congestion. The working mechanism is dynamic and distributed. Dynamic means its setting the transmission rate value depending on the status of the vehicular networks, and distributed is related to the independence of each node in the vehicular communication.

Tabu Search procedure can be described in the following steps: generating initial solution, encoding the resolution, listing the condition and defining the neighborhood solution. Tabu search is consist of some parameters and it's considered during the procedure work such as objective function, initial value, candidate list, memory, Tabu search list and terminating conditions. The length of the Tabu list and number of iterations with objective function has a significant effect on the search algorithm. According to the challenges of congestion in VANET, the element should be defined based on the feature and determine both the transmission range and rate. The approach aims are to minimize the delay, jitter and number of transmissions, especially emergency messages in vehicular communication.

In order to find the feasible solution in the list of neighbors this is done through defining some values, then finding the transmission range among the standard values. Those values that have a minimum value of jitter and delay will be selected as the best solution among the available values. One more solution that added to the search is the memory technique. Two terms have been used in the memory mechanism which is the long term and short term. In the short-term approach, Tabu technique is the forbidden solution. Tabu list is compared with the new solution before been selected as the best solution, if the new solution is available in the Tabu list, then it will be ignored in order to reduce the duplication in the available solution. If the optimum solution is chosen, then it will be inserted into the list of Tabu. Finally based on the Tabu capacity the best solutions will stored (Taherkhani and Pierre, 2015).

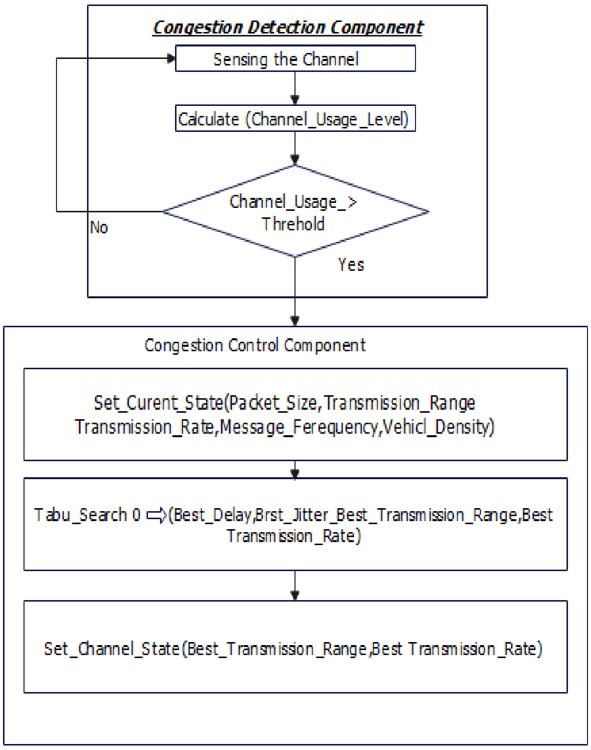

Figure 8: Congestion control strategy diagram

The second term in the memory mechanism is the long-term storage mechanism which are used to concentrate and select of best solution. This approach focuses on search in the region of the solution, the location will select based on the recent solution in the Tabu list and the neighborhood of the best solutions. The purpose of selecting the new solution from the previous Tabu list is to generate the initial solution. Based on the different metrics such as the number of iterations and expected time, the search algorithm will terminate the rules through the last elements in Tabu. Finally for setting the transmission range and transmission rate, multi-metric is applied in the search with considering the delay and jitter as the objective functions.

4.1.2.2 Power-based Congestion Control

Many algorithms are suggested in VANET to mitigate the congestion based on different parameters (Joseph et al.,2018). Segment-based Power Adjustment for VANET (SPAV) is used to reduce the congestion of vehicles base on some value that is extracted from the location of each vehicle in the communication range. To calculate the required power that is needed to send the beacon to available nodes. The suggested algorithm computed the transmission rate for all the nodes based on their position, then found the maximum distance which node can send with some specific value to mitigate the congestion. The proposed technique is preferable when we have smaller number of vehicles in the environment. Because the procedure need time to calculate the transmission rate and find the position to determine the limitation for each node, this procedure causes network overhead in very high density vehicular **(**Egea-Lopez., 2018)

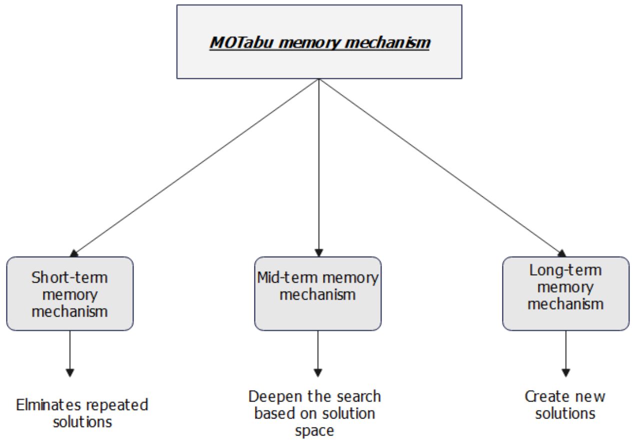

Figure 9: MOTabu memory strategies

4.1.3 Multi-metrics Overhead-based Congestion Control

Overhead-based is one of the important metrics that are considered in vehicular communication, in order to mitigate the congestion in VANET. As mentioned before in the previous part many algorithms have been suggested here, Multi-objective Overhead Routing Scheme (MORS) is proposed. MORS algorithm is based on many metrics, for instance, probability of reception rate (PRR) and Distance (D) in vehicular communication (Goudarzi et al., 2019)**.**

The multi-metrics Overhead Routing Scheme mechanism consists of two approaches for congestion control in VANET. Fully Distributed congestion control approach (FDCC), and unicast multi-hope data dissemination (UMDD). FDCC mechanism which is the force that each node has to calculate its power adaptation, FDCC is computing the energy of the node in order to count the distance and considering the connectivity density of vehicles. UMDD which is second face of MORS, this approach is focus on the relay of the next node which is based on the RPP with maximizing the distance/communication density. The purpose of using the RPP is to choose the best next forward node in communication range and reduce the propagation delay.

Fully Distributed Congestion Control to guarantee the transferring of messages according to the status of the vehicular network in term of connectivity density of VANET. FDCC is one of the distributed congestion controls which is determining the node load through the setting the power of each node, which is each node calculating the connectivity density. By determining the power of each node, the node limits its detection range, means bigger transmission range of vehicles, this will affect the transmission of other vehicles with the transmission collision, also the bigger transmission range of vehicles, so the bigger its detection range, which is lead to sense the traffic of other vehicles. The optimization process to control the congestion in VANET, is to increase the hope number of transmission range by limiting the threshold (Jiang et al., 2008).

Table 2: Closed-loop Congestion Control Mechanism Based on Different Metrics

Algorithm Name	Implantation	Channel	Performance Metrics
DD-FPAV	Ns2 with Sumo	Control channel	Event-driven messages
Cross layer technique	WARP2	Control and service channel	Event-driven messages
PULSAR	Omnet++ with Sum	Control and service channel	Event and measurement driven messages
MD-DCC	Ns2 with SUMO	Control and service channel	Event-driven messages

Multi Objective MOTabu	SUMO, Move, Ns2	Control and service channel	Event and measurement driven messages
Meta-heuristics	Ns2	Channel switching	Event and measurement messages
Tabu-search	SUMO	Control and service channel	Event-driven messages
SPAV	Ns2	Control channel	Event-driven messages
MORS	Ns2	Control and service channel	Event and measurement messages
FDCC	Omnet++ with SUMO	Control channel	Event and measurement messages
UMDD	Ns2 with SUMO	Control and service channel	Event and measurement messages

Overhead have a significant impact on mitigating of congestion in vehicular communication. Unicast Multi-hop Data Dissemination (UMDD) is another algorithm that has been suggested to reduce congestion. The mechanism working of UMDD is based on the Multi hope packets forwarding such as real-time measurement, link quality and delay, in order to disseminate the information to the specific region in vehicular communication. UMDD is combining many parameters as mentioned before and selecting the best next forwarding node among available neighbors in the region to select the best one to disseminate the information. The probability of the reception rate of the neighbor is dependent on the quality of available links. Distance also affects the delay which is minimized by reducing the number of hopes. Overhead is minimizing by minimizing the number of hopes dissemination delay in communication range which is lead to minimize the congestion (Tonguz et al., 2010).

The quality of the available link has a significant effect on vehicular communication. Communication links in UMDD can be evaluated in VANET by following many parameters such as, life time duration of the link and the connection period. UMDD also consider the probability of reception PRR and the path between the source and the destination in communication range to choose the best candidate for forwarding the packet which is result to reduce the congestion in the communication range (Killat et al., 2007).

4.2 Open-loop congestion control Techniques

The second approach of congestion control in vehicular communication is Open-loop. Working mechanism of this approach is running before the congestion occur, the amins of this technique is to avoid the congestion. Here the priority and scheduling has been considered, so in this part, we will explain three strategies, such as Priority, topology and adaptive based in which is followed in vehicular network. Table 3 describes the available mechanism of open-loop congestion control in VANET.

4.2.1 Location and priority-based congestion control

One of the big challenges in VANET is the congestion occurrence during vehicular communication. Many types of researches today concentrate on how to increase the quality of service in VANET in terms of connectivity, safety, non-safety messages and communication reliability. For this reason, some mechanism has been suggested to improve the quality of services such as Dynamic Schedule and Static Schedule (Taherkhani and Pierre, 2016). The approaches mentioned before give a priority to the packets that are travelled depending on the packet size, packet content and network usage and these mechanisms are applied before the congestion happen in VANET.

There are two sections that are followed by the VANET to prevent the occurrence of congestion control. These sections are the priority assignment technique and message schedule unit. Priority assignment give the priority to the safety application, which is depend on the static and dynamic metrics. The message scheduling resorts the priority of packets in both types of channel list. Message scheduling is following a specific mechanism for controlling the congestion which is distributed, the mechanism gives each node in vehicular communication to assign the priority. Also, schedule the packet which is different from one node to another (Ishaq et al., 2018). The main idea behind this approach is the open-loops technique is to prevent congestion control to be occurred based on the priority and schedule of packets. Due to vehicles in VANETs have independent priority and schedule the messages.

The figure below shows both priority assignment and message schedule techniques.

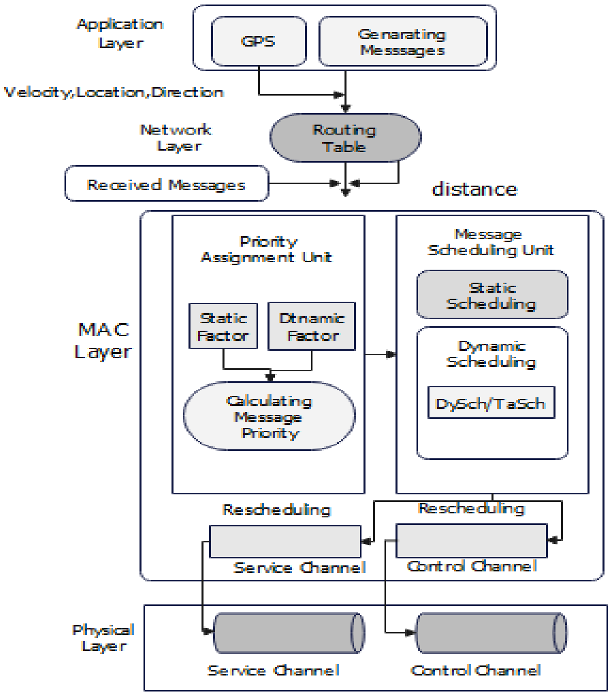

Figure 10: priority and schedule congestion control diagram**.**

In the priority assignment section, the mechanism is to give the priority value to the each created packet or received from the other vehicles in the transmission range. Based on the priority number that has been assigned to the packets, the transmission rate will be determined which is dependent on the static and dynamic, in addition to the message size. The relationship between the priority number that is assigned to the messages and the static, dynamic schedule in terms of packet size is proportional. High priority messages in vehicular communication are the safety messages and emergency messages because is the life of drivers on the roads, when the size of the message is small it will assign a higher priority number.

4.2.1.1 Static Schedule

The static schedule is determined through the type of application that is used by VANET and the message content. In the static schedule, there is a range of value that is assigned to the messages 1,2,3,4 or 5, if the message priority is one of the following: service priority, safety priority, and beacon or emergency priority. Low priority is assigned to the messages that are created by the application that has low priority, for example, instant messaging between the vehicle's nodes, applications that serves parking position indicator, payments services, connection service, and so on. High priority is given to the messages that are generated by the programs and applications which have high priority, for instance, application of traffic flow and global position system and application of map (Pesel and Maslouh, 2011). In vehicular communication there are many applications which deal with the safety warming, these messages counted as low priority, which is defined by the application of car collision, changing the lane on the roads, not allowed parking area and the places of turning.

In vehicular communication the nodes periodically broadcast messages to them, the beacon is a message which is used and it is counted as safety messages, this message contained some important information regarding the vehicles such as the location of the vehicles, velocity, and path of the vehicles (Kargl, 2006). Those messages that have maximum priority than other messages in VANET, is called the emergency messages which are very important and it should deliver with minimum delay. There are many applications that deal with this kind of message such as brake light application, alarming from emergency vehicles, car accident warning at the roads and intersection and warning messages regarding the pedestrian crossing the roads.

Overall, the mechanism working of static based schedule is depend on the priority of the packets, which is the content of message and type of the application. The message will travel over the control channel or service channel (Kumar et al., 2019). Control channel queue will be busy with transferring the messages with high priority, while messages with low priority are delivered depending on the service channel. In case of the control, channel is fully busy with high priority packets transferring the service channel will take care of delivering the messages because all messages have to deliver with minimum delay.

4.2.1.2 Dynamic Schedule

Dynamic schedule implemented using some algorithms to control the congestion in VANET. Assigning the priority to the message, Meta-heuristic approaches used for rescheduling queues. Priority number is given to each packet in order to know the priority of each message in the network. When messages transferred the queue channel going to reschedule all packets, after all packet will send to the service or control channel queues to be delivered to the medium of communication by holding one of the available channels. The parameters that are considered in the dynamic schedule are the speed of vehicles, the benefit of messages, a lifetime of the message, the direction of transmitter, receiver nodes and the distance between them. The dynamics mechanism is measured by depending on the GPS data with the routing information. Enhanced Distributed Channel Access (EDCA) and Network Coding Admission Control (NCaAC) are considered. These algorithms are used to find the priority of the messages.

Speed parameters is the speed of the message that has been sent based on the travelling range of the vehicles with some value of time t (Nahar et al., 2019). The priority here is assigned to the messages that have high-speed parameters because the nodes with high speed are expected to be disconnected within a specific area of transmission and time. EDCA is one of the algorithms which are used the message priority to deliver the packets by selecting one of the exists channel service or control for any type of messages and applications. Moreover, EDCA supports (CSMA/CA) Carrier Sense Multiple Access with Collision Avoidance the EDCA algorithm checked the transmission medium then decided to transmit the waited packets in the queue prevent the happening of collision. The challenges with EDCA are the overhead and power increasing when extra data is inserted in each message to discover the congestion (Campolo et al., 2011).

Benefits of parameters are determined based on the probability of retransmission of the messages within some specific area and overlapped area. This kind of messages will have low priority because the probability of receiving the message more than one time by surrounding vehicles is very high, so in the overlap area no needs to assign high priority to the messages, low priority is enough to be assigned. Lifetime parameters are proposed in order to assign the priority to the messages based on the validity of the message which is a residual time of the message lifetime. High priority is assigned to the message if the remaining time of message validity is short.

The distance metric is another parameter to decide on the priority of the message the relationship between the distance and the priority is proportional. If the route between the sender vehicles and receiver vehicles is long, the priority will be very high and vice versa when the distance is short the priority will be low. Direction parameters also have an effect on the congestion in VANET. When the sender and receiver vehicles drive close to each other, or they are driving in opposite directions to each other, also, If the sender vehicles driving to be close to the receiver. In this case, a low priority will be assigned to the message. In case both the sender and receiver driving in opposite direction mean the distance will be increased and the probability of disconnection will be very high, that way a high priority will assign to the message.

In NCaAC (Wang et al., 2020) Network coding aware admission control, using a network coding mechanism is considered in order to reduce the congestion in vehicular communication. Within the assistance of the RSU roadside unit which is deal with messages in two models low and high priority, then delivered it to the control and service channel. When the network density is high in the region, the RSU perform the load balancing which is minimizing the congestion. The advantages of using NCaAC are bandwidth utilization and minimum packet loss, while the disadvantage of NCaAC is power consumption and network overhead.

4.2.2 Topology-based congestion control

These mechanisms have two type of network structure for controlling the congestion which is the centralized and distributed.

The centralized approach in vehicular communication depends on the Roadside unit (RSU) which is placed on the roads for controlling and monitoring the vehicles. The main point RSU used to determine the signal metrics such as network traffic, location of nodes, direction, vehicle break conditions of the neighbor vehicles, in addition to providing the vehicles with route information to select the optimum path (Navdeti et al., 2019) and (Khan and Lee, 2019). VANET counted the centralized approach as the best in some cases because it reduces the network overhead and is preferable to keep the connectivity of topology with the help of RSU. There are many techniques in VANET depending on the centralized mechanism such as robust congestion control technique, bandwidth allocation technique, Adaptive-Transmission rate value-based, Load Balancing, and Available Resource techniques. The techniques below following the centralized metrics-based mechanism to control the congestion (Usha and Ramakrishnan, 2020).

4.2.2.1 Robust congestion control

This technique is one of the topology-based centralized mechanisms which is used to reduce congestion in vehicular communication (Usha and Ramakrishnan, 2020). Priority number and a number of hope that the message takes to reach the destination is considered by the congestion detection approaches, in addition to some parameters such as packet waiting time, collision ratio, reception rate. The main idea behind this approach is to mitigate the congestion by utilization the transmission energy and transmission rate. However, packet loss increased with high network density, while the delay and network overhead decreased.

4.2.2.2 Bandwidth allocate-based congestion control

Bandwidth allocation technique congestion control is one of the preferable approaches in vehicular communication. Most of the technique is implemented before the congestion occurs, some cases are conducted when the service is busy with message processing so the messages are transferred to the control channel to reduce the overhead and time of transmission, resulted mitigating the congestion control. The congestion detection in this technique checks the channel status, priority of the vehicle's nodes and length of waited messages in the queue (Ghosh and Mitra, 2012). Messages priority is computed based on the message content, messes size, time of delivering the packets, and bandwidth allocates. This approach has some limitations such as overhead increased when network density increased and power consumption also increased because of transferring messages for the service channel to the control channel.

4.2.2.3 Adaptive-Transmission rate value-based congestion control

This technique used widely in vehicular communication to control the congestion used centralized topology technique in VANET. One of the main functions of roadside unit RSU is measuring the transmission rate of the messages depending on the vehicular density in the transmission range, and then RSU delivers the value of transmission rate to all nodes. Based on the receiving value from RSU, the vehicles will modify their transmission value to that value which is received from RSU, resulting in minimizing congestion control in the vehicular network. This approach provides channel utilization for those messages which have high priority (Guan et al., 2011). Transmission rate decision and modification based on received notification from RSU decreased the packet loss and overhead. However, delay is raised when the network density is increased because RSU have to check each node to generate the message based on the new value of transmission rate.

4.2.2.4 Load Balancing -based congestion control

Load balancing technique is one of the significant approaches which are considered to minimize congestion control in vehicular environment. This technique is scheduling the messages to be transmitted through the RSU which delivered this notification to all vehicles in the vehicular network. Cooperative load balancing (CLB) algorithm used Load balancing technique in terms of distributing this unit in a hot area or critical area of VANET (N et al., 2014) in order to guarantee loading balance to all available RSU in the region. RSUs based on their technologies have limited transmission range, so it affects the efficiency of RSU in very high network density. When the overloaded occur on any of the RSU, load balancing is conducted to distribute the load to available near RSU to reduce the congestion the control. However, this technique causes overhead and delay in high vehicle density (Negi et al., 2016).

4.2.2.5 Available Resource-based congestion control

Available resources are considered to control the congestion in vehicular communication, recourses in terms of buffer capacity. This approach used improved AODV to monitor both control and service channel queue to detect congestion. The leading vehicles will select among other vehicles based on the high availability of the resources, and then this vehicle will send a message to all other vehicles to tune their transmission rate, the reason behind this approach is to reduce the overhead and load in addition to the bandwidth. The advantages of this approach are decreasing the overhead and minimizing the collisions. However, path delay and packet loss are raised when the congestion occurs (Goswami and Asadollahi, 2016)

Distributed approach considered as main approach for controlling the congestion in vehicular communication, because it is the default technique for VANETs. The working procedure is to propagate number of controllers in the transmission range of vehicle network, these devices capable to collect the information regarding the beacon message. This information can be followed to analyses the status of the network such as, velocity and the transmitting time. Below are states of the art technique which is used in the decentralized for controlling the congestion in VANETs. the approaches below considering the distributed metrics-based mechanism to control the congestion.

4.2.2.6 Error-based adaptive rate congestion control

Vehicular movement is considered as a new approach for control the congestion in vehicular communication. Error Model-Based Adaptive Rate Control (EMBARC) algorithm has been suggested to schedule the messages depending on the speed of the nodes and the rate of transmission. This algorithm gives more probability to the transmission for vehicles with high movement. LIMERIC liner integrated message rate control which is followed in practice. Messages schedule depend on the nodes speed in the network, which is leads to more transmission chance for vehicles with higher movement. Scheduling events is depended on the technique of tracking error. Since LIMERIC considers the load with a limited value of the channel. Mobility pattern of vehicles on the roads will adapt and results to minimize the sending of message in EMBARC. Transmitting for high-speed vehicles will reduce the highly dynamic vehicles reduce the large tracking error compare with the pure LIMERIC method. EMBARC's follow the adaptive rate control which keeps the path of error route over the network that transmit the largely independent of channel load (Gaurav and Bansal, 2013)

4.2.2.7 CSMA/CA -based congestion control

CSMA/CA-Based congestion control approach, which is defined as very critical metrics which is followed to control the congestion in a vehicular environment. This protocol allocates the channel access for vehicles in the MAC layer, by modifying the value of the metrics for channel access such as window size and restricting the channel access for each vehicle, resulted in minimum congestion in vehicular communication. However, the end-to-end delay and network overhead increased because of allocating channels and when size of the windows increased especially in high network density with dynamic mobility of nodes (Sospeter et al., 2018).

4.2.2.8 TDMA/CA -based congestion control

Context Awareness Beacon Scheduling (CABS) mechanism is one of the decentralized approaches which is considered in vehicular communication to control and minimize the congestion occurrence. Context Awareness Beacon Scheduling algorithm used the Time Division Multiple Access (TDMA) techniques to assign the priority to the message, which is to give the priority to the messages that are more important such as emergency messages to be delivered without delay to limited the channel load and channel usage. CABS mechanism found a way to reduce the congestion that occurs when network density increased because of the high rate of beacon messages. CABS assign each node a different slot period to deliver their messages to other nodes following the TDMA. Through the virtual frame table which has enough acknowledgement about the nodes for example, velocity, direction, location of vehicles, slot time and delivery rate, this information will share between the available vehicles. Base on the available slot time the vehicles have to transmit their message, otherwise have to wait for new time slot this mechanism leads to reducing the congestion in VANET (Bai et al., 2013). However, the MAC layer has to allocate the proper time slots for each transmission.

4.2.3 Adaptive and Event-driven -based congestion

Adaptive and Event-driven mechanism is one of the most preferable techniques which are considered by the vehicular communication, the control decision of the network will change dynamically when the congestion occurs (Gupta et al., 2017). Adaptive and Event-driven provide the robustness, transmission range, and connectivity of the network. Many techniques are considering the adaptivity of the vehicular network and depending on the critical parameters such as, Speed Based, Vehicle density-based, power control, multi-metric Tx-power, Adaptive transmit power, efficient adaptive probabilistic, Joint transmission, Combined power and Beacon inter-reception time. In the next section we will explain all these algorithms which are used adaptive mechanism to control the congestion schemes in VANETs with their significant impact on the connectivity and overall network performance in vehicular communication.

4.2.3.1 Speed Based Adaptive Power Control (SBAPC)

SBAPC is one of the algorithms that are considered by VANET, which changes the control of network connectivity dynamically when the congestion is discover in the connected vehicles (Joseph et al., 2018). In SBAPC, adjusting the value of transmission in term of rate and power of each node dynamically depend on some parameters such as the velocity of the vehicles, location and channel status. The main idea behind SBAPC is minimize the collision time with surrounding vehicles when the vehicle's topology changed very rapidly. The transmission rate value can be calculated through the position of each vehicle in the transmission area, this value is used by the SBAPC to find the maximum distance that the vehicles can transmit the message and restricted with a threshold value in order to minimize the congestion. However, the consequences of the SBAPC technique are increasing end-to-end delays and network overheads.

4.2.3.2 Vehicle density-based power control (VDBPC)

This technique is followed by the vehicles Ad-Hoc network to restrict the congestion. VDBPC mechanism controls the transmission power depending on the vehicle's density in the environment within the network transmission range. The maximum transmission range of vehicles is 1000m and the messages are assigned to be transmitted maximum at a rate of 10HZ which 10 messages can be delivered every second. A number of vehicle node in the specific region is proportional to the network density of vehicles when the number of vehicles in the transmission range is more than 100, then the network counted density if less than 100 vehicles it is counted called not the crowded or sparse network. In crowded network topology messages, the transmission will be decreased which is lead to a collision. In a non-crowded environment, the transmission power will have maximum value as the congestion will be decreased. The objective of the congestion control mechanism is to notify distance nodes regarding the vehicular environment and increase the awareness of nearby nodes. This algorithm used the Power parameter to increase the transmission range and in the case of maximum power transmission some nodes which hide and channel fading will be sparse. However, congestion control in event-driven unclear because vehicles density is not fixed and randomly assumed (Liu and Jaekel, 2019).

4.2.3.3 Multi-metric Tx-power control (MPC)

Using of a Multi-metric mechanism to control the congestion in vehicular communication is based on the quality of the channel and the transmission power with a variety of coverage regions. Adapting of transmission power for each vehicle depends on the quality of the channels and the requirement of the application. Through the value of channel busy time for the last period and the load of beacon message, the channel quality can be calculated (Rawat et al., 2011). Packet size and frequency are used by all vehicles to calculate the beacon load. The benefits of beacon load are to find the load on the control channel to calculate the estimated coverage in both high and low network density and determine the transmission energy required. The adapting of transmission power based on the required transmission range and message priority. Maximum priority is given to the event-driven packets and minimum priority is given to the safety packets. Maximum power transmission when there is no congestion in the network and minimum transmission power is congestion in the network. Other situation power is utilized to prevent the congestion.

4.2.3.4 Effective and efficient adaptive probabilistic data dissemination protocol (EEADP)

The effective and efficient data dissemination is a preferable approach in vehicular communication to reduce congestion. This approach considers the distance from the sender vehicles and the available number of road segments based on some parameters to mitigate the congestion. This approach concentrates on the mechanism of minimizing broadcast messages by assigning waiting time values to each vehicle in the communication range using distance parameters. Rebroadcast is assigned to the vehicles depending on the minimum waiting time. To rebroadcast of packets, the present and redundancy of vehicle should be calculated which is the message that have been transferred to the number of messages. The issue of broadcast can be saturated by given different wait time to various road segments with the last slot chosen as the unique forwarder vehicle. Slot time with the minimum number of nodes, then the redundancy will hold maximum priority to rebroadcast. This mechanism aims to decrease the broadcast message and increase the packet delivery ratio. The increasing number of the road segments is depending on the number of vehicles on the roads, which is mitigating the vehicle density if the node density exceeded the threshold, so to preventing the congestion, number of road segment increased. This technique is preferable for safety messages (Sospeter et al., 2018).

4.2.3.5 Joint transmission power rate control (TPRC)

Main aims of this approach are to optimize the performance of reception rate for vehicular communication by finding the inter-reception time IRT at a specific distance to reduce the channel overloading. TPRC is following the idea that there is a specific value of transmission power which not related to the network density. In TPRC the network performance is enhanced through choosing the transmission power which is considering the distance parameters, while load is followed as a metric to select the proper rate and minimize the unwanted interference. In TPRC the message reception rate is analyzed for the safety application in vehicular communication. The sender node should make sure that their packets have been received within the specific distance, considering the maximum time for sending and receiving messages. TPRC algorithms check the channel load, if the load value is less than the permitted load value it will raise the transmission power for maximum load, and if the transmission is less than the maximum time, the algorithm will increase the transmission rate. This technique supports the beacons and not preferable for event-driven that are used for vehicular communication (Tielert et al., 2013).

4.2.3.6 Adaptive transmit power Cooperative Congestion Control (AC3)

Adaptive transmission power mechanism is considered to minimize the channel load and to reduce channel congestion. AC3 algorithm considers some metrics such as channel usage and vehicular network density in order to choose the proper transmission in term of ratio and power in VANET. AC3 mechanism prefers some parameters as algorithm input value to for example, maximum rate and power to mitigate the vehicles congestion. Some calculation and implementation steps are followed in the AC3 technique to find the values of transmission rate, and power, velocity and location of the vehicles in the communication range of vehicular. According to the result analyses of AC3 show that this algorithm which counted as preferable techniques to minimize channel congestion in the vehicular networks (Shah et al., 2018).

4.2.3.7 Combined power and rate control (CPRC)

The combined power and rate technique is considered in vehicular communication to control the congestion. In some cases, the parameters such as maximum collision and velocity may be needed to increase the transmission rate, especially when the transmission rate is below the threshold value. Two steps can be conducted. At the first step the transmission rate is calculated depending on the vehicle number in the transmission area, and the data rates are also measured for each transmission power of vehicle in the region with the same rate of transferring the messages. In the second step, each vehicle calculates the inter-packet arrival time for surrounded nodes, in addition to founding the packet generation rate. CPRC considerate power rate and data rate such that network load should be below the threshold value and ignore the high-speed mobility of vehicles. When a vehicle reached the specific area or dangerous cases, such as moving to different direction at the traffic intersection, these vehicles will minimis their power and give the permission to all other vehicles to receive the notification regarding the dangerous area (Baldessari et al., 2010).

4.2.3.8 Beacon inter-reception time Ensured Adaptive Transmission (BEAT)

BEAT approach consider the transferring rate of beacon and receiving time to minimize the congestion in vehicular communication. BEAT used the channel usage, time of the occupation channel with the total number of packets in the queue as metrics to detect the congestion in VANET. Based on the safety of vehicles, vehicles density the network and receiving the beacon, the BEAT will generate the beacon messages. The advantage of BEAT algorithm is provided the availability and capacity of channel for maximum priority packets and increases the channel utilization for high priority message. However, in the low priority, delay and packet loss parameters will increase whenever congestion happens because of restricted resources and bandwidth (Son and Park, 2019).

In conclusion of this section IV congestion control technique, which are explained in both mechanisms. The limitation in closed technique is maximized the delay, increased the packet loss, and collision percentage compared to open technique. Congestion control is applied after the detection of congestion. The open-loop mechanism used by many algorithms and techniques to prevent the occurrence of congestion in VANET which is a high dynamic network, and not delivering the messages because of the occurrence of interrupting links. An open method is checking the network, if the probability of congestion increased the algorithm is applied to minimize the congestion. However, some of the open methods cause network overhead and delay because of a large number of commands exchanged between the nodes to minimize the load and bandwidth. We

explained the limitation of the congestion control approaches in Section V, which is became clearer the cons and pros to the reader and the researchers. Moreover, to solve the challenges of the current congestion techniques and to introduce best efficiency of detection and control, we have recommended modern techniques in future directions

Table 3: Open-loop congestion control mechanism based on different metrics

Algorithm Name	Implantation	Channel	Performance Metrics
Prioritizing and scheduling message	Ns2 with SUMO and Move Simulation	Control and service channel	Event driven messages
Context Awareness Beacon schedule (CABS)	Qualnet 4.5	Control channel	Measurement driven
Enhanced Distributed Channel Access (EDCA)	Opnet Simulator	Control and service channel	Event and measurement driven messages
NCaAC Network coding aware admission control	Ns2 with SUMO	Control and service channel	Measurement driven
Cooperative Load balancing (CLB) [101]	CDMA Subscriber-Identity Module	Request, response channel	Measurement driven messages
Adaptive congestion control [100]	SUMO Simulator	Control and service channel	Event driven messages
EMBARC Error Model	NS2, Network	Control and service channel	Event and measurement driven

Based Adaptive Rate Control	Simulator		messages
Carrier-sense multiple access with collision avoidance (CSMA/CA)-	NS2, Network Simulator	Control channel	Measurement driven messages
Context Awareness Beacon Scheduling (CABS)	Omnet++, SUMO	Control channel	Event and measurement driven messages
Speed Based Adaptive Power Control (SBAPC)	Ns2 with SUMO	Control and service channel	Measurement driven messages
Vehicle density-based power control (VDBPC)	Ns2 with SUMO	Control channel	Event driven messages
Multi-metric Tx-power control protocol (MPC)	Omnet++, SUMO	Control channel	Event and measurement driven messages // beacon
Effective and efficient adaptive probabilistic data dissemination protocol (EEADP)	Ns2 with SUMO	Control channel	Beacon
Joint transmission power rate control (TPRC)	Omnet++, SUMO	Control channel	Beacon
Adaptive transmit power Cooperative Congestion Control (AC3)	SUMO with Ns2.35	Control channel	Event and measurement driven messages
Combined power and rate control (CPRC)	Ns2	Control and service channel	Event and measurement driven messages
Beacon inter-reception time Ensured Adaptive Transmission (BEAT)	SUMO with Ns2.35	Control and service channel	Beacon

5.Challenges and Future Work

This survey paper explained different approaches and mechanisms that are considered by the researchers today to prevent and detect the occurrence of congestion in vehicular communication. Analyzed the algorithms on different parameters that has significant effect on the performance of VANET such as, end-end-delay, throughput, etc. We also discussed many detections and control technique and their advantage and disadvantage. Due to the dynamic change of the network topology of VANET, many algorithms have been applied and when the algorithm starts working and which cases for example channel load balancing, data rate, transmission ration power adaptive, transmission rate tuning, priority and scheduling technique and so on. All these techniques have been applied to mitigate the packet loss in the density network and to prevent congestion. In the previous parts, we have explained many approaches which is considered in vehicular communication. In this part we list some possibilities and concerns which can be conducted in the future for mitigating the congestion in VANET.

1.Fairness

Fairness is necessary for vehicle network to guarantee that all nodes in the communication range have the same possibilities of connecting with neighbor vehicles in the network. Network resources are allocated and available to all vehicles equally. However, sometimes fairness causes less efficiency in terms of using the network resource management in a vehicular network. There are many applications and services in VANET, so the efficiency of nodes is very important to ensure safe communication, researchers need to reached a proper balance between fairness and efficiency. Several congestion detection and control mechanism has been approved and published which consider fairness as critical parameter and are very important, but the weakness is there is no available mechanism followed to measure fairness among the vehicular network.

2.Awareness and cloud-based

Awareness is another metric that should be considered in VANET. The ultimate aims of congestion control are to enhance the overall nodes awareness, in order to achieve safe communication among the vehicles. Awareness can count as one of the parameters used to control and detect the congestion in a vehicular network. Location awareness application can be used in VANET to easily find and determine the current position and future position of the vehicles. This information can help to categories the nodes and decide to establish the connection between the vehicular networks [p1, 126]. It’s clear that when the number of vehicles increased in a specific area’s congestion will happen. To prevent this scenario, cloud is considering to give awareness and services. In vehicles networks, the information is saved and generated in different places a unit in the vehicular network, such as vehicles, main towers RSUs, and clouds. Learning methods are required to act on some parts of data and detect the information that is received from other parts of the network. In ensuring the awareness among the vehicles, some strategies can be considered such as, multi-agent system. The cooperation between the agents has a significant effect on the available agents to increase the performance and awareness through the sharing of important information among them. Each vehicles agent is aware and has enough information about other nodes in the vehicular environment. Applying machine learning in VANET, increased the capability of each vehicle to learn what is necessary to share depending on what they received with minimal overhead.

3.Artificial intelligent-based

Nowadays, artificial intelligence is used widely in wireless communication field, especially in vehicular network VANET. We can us the AI technique to predict the location of the congestion regions in future. One of the benefits of AI has the ability to perfectly transfer the messages to different route. Low network density in vehicular communication will results in low congestion in the network. Minimum delay for safety messages is a big challenge compared to other metrics. Considering the AI with other technologies such as fog computing can manage these messages in a professional way and increase the network efficiency and data dissemination in the VANET.

6. Conclusion

Congestion detection and control are very important it’s compulsory to considered in vehicular communication because of their effect on the network performance and network connectivity in VANET. In this paper, we have surveyed the state-of-the-art technique that is considered nowadays in congestion detection and control in vehicular communication. In addition, to explain the current approaches that are used, we show the advantage and disadvantages of the existing mechanisms of congestion detection and control in VNAET. We explain the effect of using new technologies such as 3G, LTE-4G, 5G and WiMAX on the controlling of congestion. We have summarized the characteristics and feature of many algorithms and techniques that are used in VANET. We compared the available approaches based on different parameters and different environments of the implementation. Finally, we suggest some enhanced techniques to improve the working of congestion algorithms such as fairness, Awareness and cloud and artificial intelligence to eliminate the drawback of the current mechanism of congestion detection and control.

References

FEUKEU, E. A., ZUVA, T. 2020. Dynamic broadcast storm mitigation approach for VANETs, Future Generation Computer Systems, vol. 102, pp. 1097-1104.

PATTANAYAK, B. K., PATTINAIK, O., PANI, S. 2020. A novel approach to detection of and protection from sybil attack in VANET." Advances in Intelligent Computing and Communication. vol. 109, pp. 240-247.

TORRENT-MORENO,M., MITTAG,J., SANTI,P. 2009. AND H. HARTENSTEIN. 2009 Vehicle-to-vehicle communication: Fair transmit power control for safety-critical information, IEEE Trans. Veh. Technol., vol. 58, no. 7, pp. 3684_3703.

KARAGIANNIS, G., ALTINTAS, O., EKICI, E., HEIJENK, G., JARUPAN, B., LIN, K. 2011. Vehicular networking: A survey and tutorial on requirements, architectures, challenges, standards and solutions IEEE Communications Surveys & Tutorials, vol. 13, pp. 584-616.

GUERRERO-IBÁÑEZ, J., FLORES-CORTÉS, C., ZEADALLY, S. 2013. Vehicular Ad-hoc Networks (VANETs): Architecture, Protocols and Applications, Next-Generation Wireless Technologies, ed: Springer, pp. 49-70.

LIU, Y., DION, F., BISWAS, S. 2005. Dedicated short-range wireless communications for intelligent transportation system applications: State of the art, Transportation Research Record: Journal of the Transportation Research Board, pp. 29-37.

HARTENSTEIN, H., LABERTEAUX, K. 2009. VANET vehicular applications and inter-networking technologies, vol. 1: John Wiley & Sons.

NASSAR, L., JUNDI, A., GOLESTAN, K., SATTAR, F., KARRAY, F., KAMEL, M. 2012. Vehicular ad-hoc Networks (VANETs): capabilities, challenges in context-aware processing and communication gateway, Autonomous and Intelligent Systems, ed: Springer, pp. 42-49.

KAUR, M. 2012. Vehicular ad hoc networks," Journal of Global Research in Computer Science, vol. 3, pp. 61-64.

Qin, H. 2020. WiFi-Assisted control traffic offloading in vehicular environments, IEEE Transactions on Vehicular Technology, vol. 69, pp. 4542-4547.

YUNG, YI., SHAKKOTTAI, SANJAY. 2020. Hop-by-hop congestion control over a wireless multi-hop network. IEEE/ACM transactions On Networking 15, no. 133-144. VANETs," IEEE Networking Letters, vol. 2, pp. 33-37.

BHATIA, J. 2020. SDN-based real-time urban traffic analysis in VANET environment, Computer Communications, vol. 149, pp. 162-175.

BALASUBRAMANIAN, V., OTOUM, S., ALOQAILY, M., AL RIDHAWI, I., JARARWEH, Y. 2020. Low-latency vehicular edge: A vehicular infrastructure model for 5G, Simul. Model. Pract. Theory, vol. 98, Jan. 2020, Art. no. 101968.

ALOQAILY, M., BALASUBRAMANIAN, V., ZAMAN, F., AL RIDHAWI, I., JARARWEH, Y. 2018. Congestion mitigation in densely crowded environments for augmenting QoS in vehicular clouds, in Proc. 8th ACMSymp. Design Anal. Intell. Veh. Netw. Appl., Oct. 2018, pp. 49_56.

JOSEPH, MAAN, XIAOFENG LIU, ARUNITA JAEKEL. 2018. An adaptive power level control algorithm for DSRC congestion control. In Proceedings of the 8th ACM Symposium on Design and Analysis of Intelligent Vehicular Networks and Applications, pp. 57-62. 2018.

CHOUR, H., NASSER, Y., ARTAIL, H., KACHOUH, A., AL-DUBAI, A. 2017. VANET aided D2D discovery: Delay analysis and performance, IEEE Trans. Veh. Technol., vol. 66, no. 9, pp. 8059_8071, Sep.

SPAHO, E., IKEDA, M., BAROLLI, L., XHAFA, F., BIBERAJ, A., IWASHIGE, J. 2012. Performance comparison of DSDV and DYMO protocols for vehicular ad hoc networks, in Proc. IEEE 26th Int. Conf. Adv. Inf. Netw. Appl.,Mar. pp. 629_634.

ZHANG, H. Li, J. 2014. Dynamical topology analysis of VANET based on complex networks theory. Cybern. Inf. Technol., vol. 14, pp. 72_186.

ELIAS, S. J. et al., 2019. Congestion control in vehicular adhoc network: A survey. Indonesian Journal of Electrical Engineering and Computer Science, vol. 13, pp. 1280-1285.

FALLAH, Y. P., HUANG, C. L., SENGUPTA, R., KRISHNAN, H. 2011. Analysis of Informaiton Dissemination in Vehicular AdHoc Networks of Cooperative Vehicle Safety Systems", IEEE Trans. on Vehicular Technology, Vol 60, Issue 1, pp. 233-247.

MYLONAS, Y., LESTAS, M., PITSILLIDES, A., IOANNOU, P., PAPADOPOULOU, V. 2015. Speed adaptive probabilistic flooding for vehicular ad hoc networks. IEEE Trans. Veh. Technol., vol. 64, no. 5, pp.

SINGH, S., SAXENA, N., ROY, A., KIM, H. 2017. A survey on 5G network technologies from social perspective. IETE Technical Review, vol. 34, pp. 30-39.

Balasubramanian,V., Otoum,S., Aloqaily,M., Al Ridhawi, I., Jararweh,Y. 2020. Low-latency vehicular edge: A vehicular infrastructure model for 5G. Simul. Model. Pract. Theory, vol. 98, Art. no. 101968.

TIWARI, P., KUSHWAH, R. S. 2015. Traffic analysis for VANET using WAVE and WiMAX. International Conference on Communication Networks (ICCN). IEEE, pp. 343-346.

SINGH, J. SINGH, K. 2018. Congestion control in vehicular ad hoc network: A review. in Next-Generation Networks, Springer, pp. 489-496.

AHMADZADEGAN, M. et al. 2019. Implementation and evaluation of the impact of traffic congestion on the detection of the missing packets in VANET. In International conference on IoT in Social, Mobile, Analytics and Cloud, IEEE, pp. 169-175.

CHERKAOUI, B., BENI-HASSANE, A., FISSAOUI, M., ERRITALI, M. 2019. Road state novel detection approach in VANET networks based on Hadoop ecosystem. Wireless Personal Communications, vol. 107, pp. 1643-1660.

CHERKAOUI, B., BENI-HASSANE. A., FISSAOUI, M., ERRITALI, M. 2019. Road traffic congestion detection in VANET networks. Procedia Computer Science, vol. 151, pp. 1158-1163.

WANG, R., XU, Z., ZHAO, X., HU, J. 2019. V2V-based method for the detection of road traffic congestion. IET Intelligent Transportation Systems, vol. 13, pp. 880-885.

SOUSA, R., BOUKERCHE, S., A., LOREIRO, A. A. 2020. A distributed and low-overhead congestion control protocol for vehicular ad-hoc network. Computer Communications, vol. 23, pp. 230-245.

YAQOOB, S. ET AL. 2019. Congestion avoidance through fog computing in internet of vehicles. Journal of Ambient Intelligence and Humanized Computing, vol. 10, pp. 3863-3877, 2019.

CHENG, X., HUANG, B. 2019. A center-based secure and stable clustering algorithm for VANETs on highways. Wireless Communications and Mobile Computing, vol. 2.

BISWAS, P., SAMANTA, T. 2020. True Event-Driven and Fault-Tolerant Routing in Wireless Sensor Network. Wireless Personal Communications, vol. 20, pp. 1-23.

BOUASSIDA, M. S., SHAWKY, M. 2018. On the congestion control within VANET. in Wireless Days,IEEE, pp. 1-5.

TAHERKHANI, N., PIERRE, S. 2015. Improving dynamic and distributed congestion control in vehicular ad hoc networks. Ad Hoc Networks, vol. 33, pp. 112-125.

FUEKEU, E. A., ZUVA, T. 2017. DBSMA approach for congestion mitigation in VANETs. Procedia Computer Science, vol. 109, pp. 42-49.

Manjoro, W. S., Dhakar,M., Chaurasia,B. K. 2016. Traffic congestion detection using data mining in VANET.in IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS), IEEE, pp. 1-6.

TAHERKHANI, N., PIERRE, S. 2016. Prioritizing and scheduling messages for congestion control in vehicular ad hoc networks. Computer Networks, vol. 108, pp. 15-28, 2016.

ZEROUAL, A., HARROU, F., SUN, Y. 2019. Road traffic density estimation and congestion detection with a hybrid observer-based strategy. Sustainable cities and society, vol. 46, pp. 1-15.

SHI, Q., WANG, F., FENG, D., XIE, W. 2019. Adaptive load balancing based on accurate congestion feedback for asymmetric topologies. Computer Networks, vol. 157, pp. 133-145.

HE, J., CHEN, H. H., CHEN, T. M., CHENG, W. 2010. Adaptive congestion control for DSRC vehicle networks. IEEE Communications Letters, vol. 14, pp. 127-129.

TAHERKHANI, N., PIERRE, S. 2015. Congestion control in vehicular ad hoc networks using meta-heuristic techniques. in International Conference on Design and Analysis of Intelligent Vehicular Networks and Applications. ACM, pp. 47-54.

Araújo, G. B., Queiroz,M. M., de LP Duarte-Figueiredo, F. 2014 A. I. Tostes, and A. A. Loureiro .CARTIM: A proposal toward identification and minimization of vehicular traffic congestion for vanet. in IEEE Symposium on Computers and Communications (ISCC: IEEE, pp. 1-6.

Liu, X., Jaekel, A. 2019. Congestion control in V2V safety communication: problem, analysis, approaches. Electronics, vol. 8, pp. 540-565,

Gulik, K., Phillipson,van F., Fouchal,H. 2019. Congestion control in a location service for VANETs," in International Conference on Mobile, Secure, and Programmable Networking, 2019: Springer, pp. 289-293.

LI, S. ET AL. 2019. TCGMAC: A TDMA-based MAC protocol with collision alleviation based on slot declaration and game theory in VANETS. Transactions on Emerging Telecommunication Technologies, vol. 30, pp. 1-12.

BELLACHE, T., SHAGDAR, O., KALLEL, S., TOHME, S. 2017. Reducing channel load by enhanced contention-based forwarding in vehicular networks. International Conference on Selected Topics in Mobile and Wireless Networking (MoWNeT), 2017: IEEE, pp. 1-6.

Sharma,S. M., Chahal, A., Harit, S. 2019.Transmission rate-based congestion control in vehicular ad hoc networks. in Amity International Conference on Artificial Intelligence (AICAI) IEEE, pp. 303-307.

WILLIS, J. T., JAEKEL, A., SAINI, I. 2017. Decentralized congestion control algorithm for vehicular networks using oscillating transmission power. in Wireless Telecommunications Symposium (WTS) IEEE, pp. 1-5.

RATH, M., PATI, B., PATTANAYAK, B. 2019. Mobile agent-based improved traffic control system in VANET. Integrated Intelligent Computing, Communication and Security, vol. 109, pp. 261-269.

MATH, C. B., LI, H. S., DE GROOT, H., NIEMEGEERS, I. 2017. A combined Fair decentralized data-rate congestion control for V2V communications, in International Conference on Telecommunications (ICT), IEEE, pp. 1-7.

BANSAL, G., KENNEY, J. B. 2013. Controlling congestion in safety-message transmissions: A philosophy for vehicular DSRC systems. IEEE Vehicular Technology Magazine, vol. 8, pp. 20-26.

CHEN, C., HU,J., SUI,J., ZHOU,Y. 2017 An information congestion control scheme in the Internet of Vehicles: A bargaining game approach. Computers & Electrical Engineering, vol. 58, pp. 282-298.

ZHANG, L., VALAEE,S. 2016. Congestion control for vehicular networks with safety-awareness. IEEE/ACM Transactions on Networking (TON), vol. 24, pp. 3290-3299.

JABBARPOUR, M. R., NOOR,R. M., KHOKHAR,R. H., KE,C.-H. 2014. Cross-layer congestion control model for urban vehicular environments. Journal of Network and Computer Applications, vol. 44, pp. 1-16.

ZHANG,J., TOWHIDLOU,V., BAHAEI,M. R. 2020. A priority-based cross-layer design for future VANETs through Full-Duplex Technology. IEEE Transactions on Vehicular Technology, vol. 69, pp. 4548-4563.

DARUS, M. Y., BAKAR, K. A. 2011. Review of congestion control algorithm for event-driven safety messages in vehicular networks. International Journal of Computer Science Issues (IJCSI), vol. 8, pp. 49-62.

CHO,B. M., JANG,M. S., PARK,K. J. 2020 . Channel-Aware congestion control in vehicular cyber-physical systems. IEEE Access, vol. 8, pp. 73193-73203.

BABAGHAYOU, M., LABRAOUI, N. 2019. Transmission range adjustment influence on location privacy-preserving schemes in VANETs. In International Conference on Networking and Advanced Systems (ICNAS) IEEE, pp. 1-6.

ARAVINDHAN, K., DHAS,C. 2019. Destination-aware context-based routing protocol with hybrid soft computing cluster algorithm for VANET. Soft Computing, vol. 23, pp. 2499-2507.

NEBBOU,T., FOUCHAL,H., LEHSAINI,M., AYAIDA,M. 2017. An urban location service for VANETs. Concurrency and Computation: Practice and Experience, vol. 1, pp. 1-14.

PARANJOTHI,A., KHAN, M. S., ATIQUZZAMAN,M. 2018. HYBRID-VEHCLOUD: An Obstacle Shadowing Approach for VANETs in Urban Environment. in IEEE Vehicular Technology Conference, IEEE, pp. 1-5

TANENBAUM A. S. 2014. Computer networks, 5-th edition. ed: Prentice Hall.

JABBARPOUR,M. R., NOOR,R. M., KHOKHAR,R. H., KE, C.-H. 2014. Cross-layer congestion control model for urban vehicular environments. Journal of Network and Computer Applications, vol. 44, pp. 1-16.

SEPULCRE,M., MITTAG,J. SANTI,P., HARTENSTEIN, H., GOZALVEZ, J. 2011. Congestion and awareness control in cooperative vehicular systems. Proceedings of the IEEE, vol. 99, pp. 1260-1279.

BOUASSIDA, M. S., SHAWKY, M. 2008. On the congestion control within VANET. Wireless Days, WD'08. 1st IFIP, pp. 1-5, 2008.

TIELERT,T., JIANG,D., CHEN,Q., DELGROSSI, L., HARTENSTEIN, H. 2011. Design methodology and evaluation of rate adaptation-based congestion control for vehicle safety communications. in IEEE Vehicular Networking Conference (VNC: IEEE, pp. 116-123.

EGEA-LOPEZ,E. 2016. Fair distributed congestion control with transmit power for vehicular networks. In International Symposium on A World of Wireless, Mobile and Multimedia Networks, IEEE, pp. 1-6.

GOUDARZI,F., ASGARI,H., RAWESHIDY, H. S. 2019. Fair and stable joint beacon frequency and power control for connected vehicles. Wireless Networks, vol. 25, pp. 4979-4990.

JIANG, H., GUO,H., CHEN,L. 2008. Reliable and efficient alarm message routing in VANET. in: The 28th International Conference on Distributed Computing Sys-tems Workshops.

TONGUZ,O.K., WISITPONGPHAN,N. B. 2010. DV-CAST: A distributed vehicular broad-cast protocol for vehicular ad hoc networks. IEEE Wirel. Commun. 17(2) 47–57.

KILLAT, M. ET AL. 2007. Enabling efficient and accurate large-scale simulations of VANETs for vehicular traffic management. in International Workshop on Vehicular ad hoc networks,ACM, pp. 29-38.

Ishaq,M., Malik,M., Aydin,M. 2018. Managing congestion in vehicular networks using tabu search. In International Conference on Engineering Applications of Neural Networks, Springer, pp. 118-129.

PESEL, R., MASLOUH,O. 2011. Vehicular Ad Hoc Networks (VANET) applied to Intelligent Transportation Systems (ITS). Universite de Limoges, France,149.

KARGL,F. 2006. Vehicular communications and VANETs. Talks 23rd Chaos Communication Congress.

KUMAR,R., PAL,R., PRAKASH,A., TRIPATHI,R. 2018 A collective scheduling algorithm for vehicular ad hoc network. Recent Trends in Communication, Computing, and Electronics, vol. 52, pp. 165-180.

NAHAR, K., SHARMA,S., CHAHAL,M., HARIT,S. 2019. A review on congestion control in vehicular ad hoc network at MAC layer. In International Conference on Sustainable Computing in Science, Technology and Management, SSRN, pp. 1-6.

CAMPOLO, C., MOLINARO, A., VINEL, A., ZHANG, Y. 2011. Modeling prioritized broadcasting in multichannel vehicular networks. IEEE Transactions on Vehicular Technology, vol. 61, pp. 687-701.

WANG, S., ZHANG, Q., LU,S. 2020. NCaAC: Network Coding-aware Admission Control for prioritized data dissemination in vehicular ad hoc networks. Wireless Communications and Mobile Computing, vol. 20, pp. 1-14.

NAVDETI, C., GIRI, C., BANERJEE, I. 2019. Distributed α-fair transmit power adaptation-based congestion control in VANET. In International Conference on Distributed Computing and Networking, ACM, pp. 253-260.

KHAN, U., LEE, S. 2019. Multi-layer problems and solutions in VANETs: A review. Electronics, vol. 8, pp. 1-19.

USHA, M., RAMAKRISHNAN, B. 2020. Robust MPR: a novel algorithm for secure and efficient data transmission in VANET. Wireless Personal Communications, vol. 110, pp. 355-380.

Ghosh, T., Mitra,S. 2012. Congestion control by dynamic sharing of bandwidth among vehicles in VANET. in Intelligent Systems Design and Applications (ISDA) Conference, IEEE, pp. 291-296.

Guan,W., He,J., Bai,L., Tang,Z. 2011. Adaptive congestion control of DSRC vehicle networks for collaborative road safety applications. in Local Computer Networks (LCN) Conference, IEEE, pp. 913-917.

N, G. M., Ali, M. A., Mollah,S., Samantha,S. K., Mahmud,S. 2014. An efficient cooperative load balancing approach in RSU-based vehicular ad hoc networks. in Control System, Computing and Engineering (ICCSCE) Conference,IEEE, pp. 52-57.

Negi,Sarita., Singh,Smita., Goel,S.K., Kumar, Akshay. 2016. Data scheduling in VANET: A survey.published to. IJCST, Vol. 4(2), pp.25-31

Goswami, B., Asadollahi, S. 2016. Novel approach to improvise congestion control over vehicular ad hoc networks (VANET). in International Conference on Computing for Sustainable Global Development (INDIACom), IEEE, pp. 3567-3571.

Gaurav, Bansal., Lu, Hongsheng. 2013 John B. Kenney, and Christian Poellabauer. "EMBARC: Error model based adaptive rate control for vehicle-to-vehicle communications." In Proceeding of the tenth ACM international workshop on Vehicular inter-networking, systems, and applications, pp. 41-50.

Sospeter,J., Wu,D., Hussain,S., Tesfa,T. 2018. An effective and efficient adaptive probability data dissemination protocol in VANET. Data, vol. 4, p. 1.

Bai,S., Oh,J., Jung,J.-i. 2013. Context awareness beacon scheduling scheme for congestion control in vehicle-to-vehicle safety communication. Ad Hoc Networks, vol. 11, pp. 2049-2058.

Gupta,N., Prakash,A., Tripathi,R. 2017. Adaptive beaconing in mobility aware clustering-based MAC protocol for safety message dissemination in VANET. Wireless Communications and Mobile Computing, vol. 21, pp. 1-15.

Joseph,M., Liu,X., Jaekel,A. 2018. An adaptive power level control algorithm for DSRC congestion control. in ACM Symposium on Design and Analysis of Intelligent Vehicular Networks and Applications, ACM, pp. 57-62.

Liu, X., Jaekel, A. 2019. Congestion control in V2V safety communication: Problem, analysis, approaches. Electronics, vol. 8, no. 5, p. 540.

Rawat,D. B., Popescu,D. C., Yan,G., Olariu,S. 2011. Enhancing VANET performance by joint adaptation of transmission power and contention window size. IEEE Trans. arallel Distrib. Syst., vol. 22, no. 9, pp. 1528_1535.

Sospeter,J., Wu,D., Hussain,S., Tesfa,T. 2018. An effective and efficient adaptive probability data dissemination protocol in VANET. Data, vol. 4, p. 1.

Tielert, T., Jiang,D., Hartenstein,H., Delgrossi,L. 2013. Joint power/rate congestion control optimizing packet reception in vehicle safety communications. in Proc. 10th ACM Int. Workshop Veh. Inter-Netw., Syst., Appl. (VANET). New York, NY, USA: ACM, pp. 51_60.

Shah,S. A. A., Ahmed,E., Rodrigues,J. J., Ali,I., Noor,R. M. 2018. Shapely value perspective on adapting transmit power for periodic vehicular communications. IEEE Transactions on Intelligent Transportation Systems, vol. 19, pp. 977-986.

Baldessari,R., Scanferla,D., Le, L., Zhang,W., Festag,A. 2010 Joining forces for VANETs: A combined transmit power and rate control algorithm, in Proc. 7th Int. Workshop Intell. Transp., Mar. 2010, pp. 1_5.

Son, S., Park,K. J. 2019. BEAT: Beacon inter-reception time Ensured Adaptive Transmission for vehicle-to-vehicle safety communication. Sensors, vol. 19, pp.