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An Analytical Review of the Algorithms Controlling Congestion in Vehicular Networks

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Abstract: *Vehicular AdhocNETworks (VANETs) relies on repetitive data exchange among vehicles and vehicles to RoadSide Units (RSU) to facilitate road safety, route planning, etc. This may often lead to congestion in the network. To deal with this dilemma, various congestion control schemes have been considered so far. The basic objective of congestion control is to best utilize the available network resources while preventing persistent overloads of network nodes and links. Suitable congestion control mechanisms are essential to maintain the competent operation of a network. This paper highlights attributes of some of the proposed congestion control algorithms and compares their qualities and limits.*

Keywords: *Congestion Control, Control Channel, DSRC, IEEE 802.11p, VANETs, WAVE.*

I. Introduction

Vehicular AdhocNETworks(VANETs) have set a new example for wireless communications that aim to exploit the recent advances in wireless device's technology to enable intelligent inter-vehicle communication, in particular, and road safety as a whole. It has been envisaged from Intelligent Transportation System (ITS). The US Federal Communications Commission (FCC) has allocated Dedicated Short Range Communications (DSRC) spectrum at 5.9 GHz for VANETs. To be precise, VANET is a form of Mobile Ad hoc Network (MANET), in which vehicles form a decentralized network of communicating via On-Board Units (OBUs). VANET is different from MANET in numerous perspectives such as nodes in VANET are characterized by high dynamic and mobility, high rate of topology changes and density variability along with the challenging characteristics of MANETs such as lack of established infrastructure, wireless links, multi-hop broadcast communications. One major difference between the MANET and VANETs is that in MANETs nodes move randomly whereas in VANETs nodes mainly follow a predefined path as the movement is expected on roads only.

VANETs communication can be broadly classified into two categories; Vehicles communicating with Roadside infrastructure (V2R) and with nearby Vehicles (V2V) and is generally described as V2Xcommunication. A RSU is an intelligent device deployed across the road network that provides an external interface to the vehicle. VANET applications can further be divided into two major classes; safety and non-safety applications. Applications that are critical to human life are placed under safety application category, e.g., pre-crash sensing, post-crash warning, pedestrian/children warning etc. and non-safety applications include toll collection, mobile internet, infotainment and many more. Nodes in VANETs broadcast safety and non-safety messages to support these applications. In fact, the Society for Automotive Engineers (SAE) [23] and the IEEE Wireless Access to Vehicular Environment (WAVE) standard [18] have defined a special type of "heartbeat" message that should be periodically broadcast by vehicles to inform one-hop neighbors of their locations, directions, travel and speeds, etc.

The rest of the paper is structured as follows: Section 2 gives an overview of congestion control issue within VANETs along with a brief introduction to traffic flow theory. Section 3 comprises of a detailed overview of DSRC along with WAVE and IEEE 802.11p standards. Section 4 summarizes some typical congestion control algorithm proposed in recent years. Section 5 provides a tabular overview of the functions and characteristics of proposed congestion control algorithms for comparisons. Section 6 concludes paper along with an outlook to the future work.

II. Congestion Control In VANETs

Researches in VANETs have highlighted several multifaceted issues to be focused on, including rapidly changing topology, lack of connectivity redundancy, robust message delivery and so on. Congestion control is one of the major challenging issue within VANETs. It should take into account the characteristics of VANET while ensuring the quality of service, required by the applicative level. As discussed earlier, VANETs differs from MANETs in numerous ways, therefore, typical MANET protocols e.g. table driven routing protocols are not appropriate for VANETs as they suffer from outdated neighbor information. The dominant form of communication on the wire-line Internet and conventional MANETs is unicast end-to-end communication. In VANETs, the prevailing form of communication is broadcast/geocast. Most applications in VANETs aim to provide information on the local vicinity, which has been sensed by vehicles nearby, and hence, VANETs are more prone to congestion as compared to other wireless networks due to the broadcasting nature of VANETs. Accidents, construction work, weather condition, increase in traffic volume and poor traffic signal timing are some reasons for vehicle traffic congestion.

One of the main reasons for vehicular congestion is the increase in traffic volume above the road capacity. Interestingly, the basic concept of congestion in VANETs remains the same as used in the computer communication network wherein a network node gets congested when there is demand for more bandwidth than available capacity. As a result of congestion, a queue starts filling up and sooner or later, as the buffer is finite, there will be no room for newly arrived packets. The same concept is pertinent to VANETs in which, if we consider the road as a queue and each vehicle as a packet in the queue, once the road capacity is reached, there will be no room for any more vehicles. On the contrary, Congestion control schemes in Internet are based on an end-to-end paradigm, for instances, the Transport Control Protocol (TCP) at the endpoints detects overload conditions at intermediate nodes. In case, when congestion is sensed, the source reduces its data rate. However, in VANETs the topology fluctuates within seconds and a congested node used for forwarding a few seconds ago might not be used at all, at the point in time, when the source reacts to the congestion.

2.1 Traffic flow theory

Traffic flow is the study of interactions between vehicles, drivers, and infrastructure (including highways, signage, and traffic control devices), with the aim of understanding and developing an optimal road network with efficient movement of traffic and minimal traffic congestion problems. A number of traffic flow theory has been proposed in recent years. Hence, there is a large interest in understanding the relation between traffic flow J (typically measured in vehicles per hour and lane) and vehicle density ρ (vehicles per kilometer) both from a theoretical and from a practical point of view [25]. This relation can be expressed in the form of the fundamental diagram, as in Fig. 1. Here ρ_{min}^{free} denotes the minimum numbers of vehicles that can travel at their desired speed and ρ_{max}^{free} defines the maximum amount of vehicles that can travel at their desired speed. For low and high densities, its shape is easy to understand. At low densities, $\rho < \rho_{min}^{free}$ vehicles can travel at their desired speed, and additional vehicles linearly increase the total flow. At high densities, $\rho > \rho_{max}^{free}$, on the other hand, vehicles hinder each other and force others to slow down. For these two regions, the functional relation between flow and density can be expressed by the linear equation $J = v\rho$, where v stands for the average velocity of vehicles on the considered road segment. Between these two regions, nevertheless, there exists a metastable range $\rho_{min}^{free} < \rho < \rho_{max}^{free}$ where a driver's desire to travel at maximum velocity and the tendency to hinder each other compete and where flow can take two values depending on the system's history.

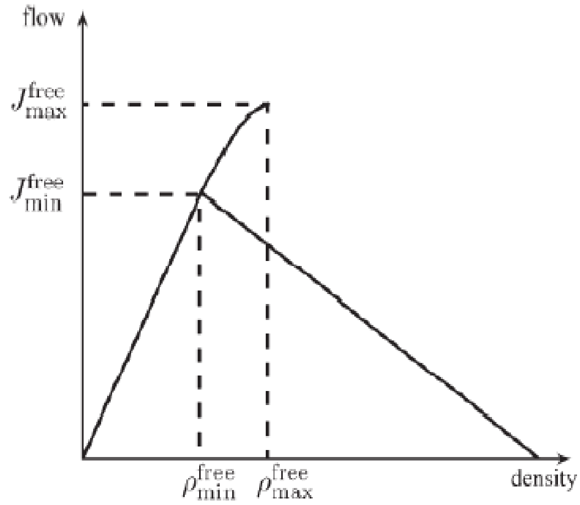

Fig.1 Schematic of a flow-density diagram showing a metastable region between ρ_{min}^{free} and ρ_{max}^{free} [25].

The flow can spontaneously switch from free (upper branch) to congested (lower branch) traffic in this density range for no obvious reason. Therefore, this occurrence is also referred to as "phantom jam".

In the recent years, researches on traffic flow theory have drawn two major conclusions:

- Traffic dynamics assessed solely by vehicle density may fail in a certain density range.
- Traffic congestion can be eased by reducing disruption of traffic flow and by keeping density below ρ_{min}^{free}.

III. Dedicated Short Range Communications (DSRC)

This section provides an overview of DSRC, the wireless communication channel allocated for VANETs. DSRC [22] was developed with a primary goal of enabling vehicular safety applications. DSRC operates in a licensed frequency band that take place over a dedicated 75 MHz spectrum band approximately 5.9 GHz, allocated by the US FCC [21] for vehicle safety applications. It provides a secure wireless interface and supports high speed, low latency and limited-range wireless communications for vehicles. Its performance is immune to extreme weather conditions (rain, fog, snow, etc.). The DSRC physical layer is adapted from the IEEE 802.11a standard using Orthogonal Frequency Division Multiplexing (OFDM) modulation, and the DSRC medium access control layer is adapted, in part, from the introductory IEEE 802.11 and IEEE 802.11e (QoS).

DSRC is preferred over Wireless-Fidelity (Wi-Fi) because the proliferation of Wi-Fi handheld and hands-free devices (e.g. Bluetooth) that dwell in the 2.4 GHz and 5 GHz bands, along with the anticipated increase in Wi-Fi hotspots and wireless mesh extensions, could cause excruciating and unmanageable levels of interference that could hamper the reliability and effectiveness of active safety applications. The normal Wi-Fi means of recognizing nearby stations and associating with them (establishing a link between two or more devices) cannot be used for active safety applications because it can take multiple seconds to complete this association. Active safety applications necessitate instant establishment of communication. A number of modifications over the basic technology (Wi-Fi) were required to achieve this goal. One of the major change is to accommodate an enormously short time in which devices must recognize each other and transmit messages to each other. Most of these safety applications require response times measured in milliseconds. As a result of which periodic transmission of safety messages is used so that vehicles receiving the safety messages can immediately determine if they should respond or not.

DSRC is similar to IEEE 802.11a, except for the major differences [24] recapitulated below:

- **Operating Frequency Band**: DSRC is targeted to operate on a 75 MHz licensed spectrum around 5.9 GHz, as contrasting to IEEE 802.11a that is allowed to utilize only the unlicensed portions in the frequency band.
- **Application Environment**: DSRC is meant for outdoor high-speed vehicle (up to 120 mph) applications, as opposed to IEEE 802.11a initially intended for indoor WLAN (walking speed) applications. In IEEE 802.11a, each and every PHY {physical) parameters are optimized for the indoor low-mobility propagation environment.
- **Medium Access Control (MAC) Layer**: The DSRC band plan consists of seven channels which include one control channel to support high priority safety messages and six service channels to support non-safety applications. Prioritizing safety over non-safety applications is an open problem that started to receive attention in the literature and is closely related to the problem of multi-channel coordination.
- **Physical Layer**: The bandwidth of each DSRC channel is 10 MHz, contrast to the 20 MHz IEEE 802.11a channel bandwidth. This provides better wireless channel propagation with respect to multi-path delay spread and Doppler effects caused by high mobility and roadway environments.

3.1 Standards

The key point of VANETs is facilitating the wireless communication among vehicles, so there is a need for developing a set of communication protocol. In view of that, IEEE defined WAVE [19] standard intended to promote wireless communication in a vehicular environment which consists of IEEE 802.11p and IEEE 1609 protocol family.

The physical and MAC layers of WAVE are based on IEEE 802.11p which covers the characteristics of vehicular ad hoc network: high dynamic mobility, high change of network topology, and low latency. The physical layer of IEEE 802.11p WAVE consists of seven channels of 10 MHz bandwidth for each channel. The physical layer of IEEE 802.11p is related to IEEE 802.11a design, but the main difference is that the IEEE 802.11p utilizes 10MHz bandwidth for each channel instead of 20MHz bandwidth in IEEE 802.11a. The physical layer of 802.11p uses OFDM technology which is used for increasing data transmission rate and overcoming signal fading in wireless communication. One of the stipulations of IEEE 802.11p is that the management functions are connected with the physical and MAC layers which are called Physical Layer Management Entity (PLME) and MAC Layer Management Entity (MLME), respectively.

3.2 Multichannel operation

IEEE 802.11p's MAC layer is enhanced by one of the standards of IEEE.1609 depicted as IEEE 1609.4 which supports multichannel operation [19]. This standard describes seven different channels with different features and usage. In addition, these channels use different frequencies and powers of transmutation.

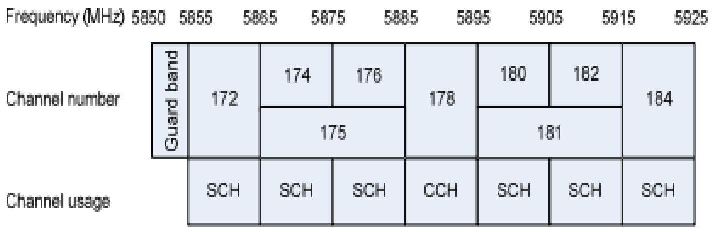

Fig.2 Frequency spectrum of DSCR[19]

As shown in fig. 2, there are six Service CHannels (SCH) and one Control CHannel (CCH) with different characteristics. Each device can alternate between the control channel and one of the service channels, but both the channels cannot be used simultaneously. The control channel is used for system control and safety data transmission. On the other hand, non-safety messages are exchanged by the six service channels. The period containing one CCH interval and one SCH interval shall last no more than 100 ms.The IEEE 802.11p MAC layer also relies on 802.11e Enhanced Distributed Channel Access (EDCA). The EDCA mechanism supports Quality Of Service (QOS) and prioritizing important safety messages.

IV. Some Proposed Congestion Control Algorithm

In recent years, VANETs have drawn attention of many researchers. The prime goal of VANETs is to provide life security on the roads. To achieve this, vehicles make use of two types of messages; i) Periodic safety messages (beacons) to exchange status information e.g. location, speed, velocities etc. ii) Event-driven messages which are broadcasted in case of an emergency situations e.g. accidents, stiff-braking etc. As both types of messages shares same Control Channel, in opaque traffic, periodic beacons may consume the entire channel bandwidth leading to a drenched/congested channel. In a congested channel, event-driven messages may not be able to access the channel at all, consequently providing no safety.

A number of algorithms have been proposed to control congestion in the vehicular adhoc network that aims at controlling the load of traffic conditions and enhancing the performance of vehicular network.

Congestion control approaches are basically classified as: end-to-end or hop-by-hop approach. **End-to-end congestion control approaches** are not suitable for VANETs as relay node's context are not considered in these approaches, and thus, interferences, collisions and transmission problems are not considered [16]. However, the required quality of service of a transmission can be defined by the sender with end-to-end congestion control approaches.

On the contrary, **hop-by-hop congestion control approaches** suffer from lack of scalability, when the amount of transmitted flows rises within the network. However, it is known that the size of the transmitted data within VANET is not considerable, due to the dynamic nature of this network, and to the node limitations in terms of storage and computation competences. Consequently, hop-by-hop congestion control approaches are the most suitable for VANET, while considering the required quality of service of the transmitted data, as for the end-to-end approaches. However, hop-by-hop congestion control approaches present some leaks to e.g. generation of communication and computation overheads, reactive congestion control techniques.

Utility-based congestion control and packet forwarding in VANETs:

L. Wischhof et al. [20] provided a concept for utility-based congestion control and packet forwarding in VANETs. The control algorithm used an application-specific utility function and encodes the quantitative utility information in each transmitted data packet in a transparent way for all users within a confined environment. A decentralized algorithm then calculates the "average utility value" of each individual node based on the utility of its data packets and assigns a share of the available data rate proportional to the relative priority. In order to achieve a large information range, a combination of broadcast data transmissions and a store-and-forward approach is used in this approach.

The algorithm in [20] totally relies on GPS receiver equipped onboard the vehicle within VANETs in order to provide the utility information required. Since GPS is not always available i.e. GPS signals cannot be received under tunnels, area characterized by high buildings, etc. accurate information of vehicles at their current road segment cannot be provided. Moreover this algorithm did not take into account the behavior of neighborhood to choose the next packet to be transmitted.

Neighborhood evaluation of vehicular ad-hoc networks:

To evaluate the role of neighborhood in VANETS, Stibor et al. [15] approximates the neighborhood nature of VANETs within a four highway lanes context (two lanes for each direction). Their simulations and analysis that show that the average number of potential communication neighbors is approximately four. In addition, in 50% of all occurrences, the maximum potential communication duration is 1 sec; in 90% of the occurrences, the upper boundary for the communication time is 5 sec.

Cooperative Collision Warning Using Dedicated Short Range Wireless Communications:

Tamer ElBatt et al. [17] directs towards periodically broadcasting short messages for the purpose of driver situational awareness and warning via vehicles. They explored two design issues that are highly relevant to Cooperative Collision Warning (CCW) applications, specific performance trends with distance and potential avenues for broadcast enhancements. The ultimate goal of CCW is to realize the concept of .360 degrees driver situation awareness, whereby vehicles alert drivers of impending threats without expensive equipment.

Furthermore, instead of end-to-end per-packet latency, they introduced a novel latency metric that reflects the critical role played by successive packet collisions in degrading the performance of periodic safety applications [17]. Moreover, they employed DGPS instead of ordinary GPS receiver to increase the range of the sensor. But here, periodic broadcast messages indicating velocities, speed and direction of vehicles within VANETs were not separated from unusual disaster messages like an accident, sudden breakdown or any mishap.

On the Congestion Control within VANET:

Mohamed Salah et al. [14] presented a congestion control algorithm that relies on the concept of dynamic priorities-based scheduling, to ensure a reliable and safe communications architecture within VANETs. Messages priorities, under this scheme, are dynamically evaluated according to their types, the network context and the neighborhood. They used UPPAAL to verify and validate their congestion control technique. UPPAAL is a tool box for validation (via graphical simulation) and verification (via automatic model-checking) of real-time systems.

A Cooperative Congestion Control Approach within VANETs: Formal Verification and Performance Evaluation:

A cooperative and fully distributed congestion control technique, based on dynamic scheduling and transmission of priority-based messages, to guarantee reliable and safe communication architecture within VANETs was proposed by Mohamed Salah et al. [9]. Considering the context of high reliability and real-time response required for inter-vehicular communications (including emergency breaking notification for example), they proposed a complete validation method of their congestion control algorithms, considering reliability, temporal, and operational facets.

Congestion Control to Achieve Optimal Broadcast Efficiency in VANETs:

In VANETs, every vehicle broadcasts update messages that contain location and speed information periodically to its one hop neighbors. Thus, broadcast efficiency measures the average rate at which a vehicle receives these packets from any of its neighbors. As the node density increases, keen interference lowers broadcast efficiency if congestion control mechanism is not used. Fei Ye et al. [10] scrutinize the broadcast efficiency under Rayleigh fading channel, and provides a congestion control and power control strategies that maximize the efficiency. A worst-case assured strategy achieving at least 95% of the optimal is also provided for cases when the network nodes have high mobility. NS-2 simulations show that their analytical results accurately predict the system dynamic.

Efficient Congestion Control in VANET for Safety Messaging:

A conceptual view of a congestion control scheme using transmission rate and transmission power control techniques simultaneously for optimal congestion control within VANETs was proposed by Bilal Munir Mughal et al. [11]. The algorithm reveals that only power control techniques do not satisfy the requirements of envisioning beacon-dependent safety applications and also methods used for measuring channel usage level in transmission rate control technique may not be as effective under real world conditions.

A Review of Congestion Control Algorithm for Event-Driven Safety Messages in Vehicular Networks:

Assigning uni-priority for event-driven messages to secure life is proposed by Mohamad Yusof Doris et al. [5]. They summarized the weaknesses and advantages of some congestion control algorithms to assist researchers to tackle the inherent problems of congestions in VANETs.

A Robust Congestion Control Scheme for Fast and Reliable Dissemination of Safety Messages in VANETs:

The periodic beacon broadcast consumes a large part of the available bandwidth leading to an escalating number of collisions among MAC frames, particularly in case of high vehicular density. This severely affect the performance of the ITS safety based applications that require timely and reliable dissemination of the event-driven warning messages. To deal with this dilemma, SoufieneDjahel et al. [4] proposed an algorithm that included three phases as mentioned: priority assignment to the messages to be transmitted / forwarded according to two special metrics, congestion detection phase, and finally transmit power and beacon transmission rate adjustment to aid emergency messages spread within VANETs. Moreover, this algorithm ensures that the most critical and nearest dangers are advertised prior to the remote and less damaging events.

Vehicle Traffic Congestion Management in Vehicular ad-hoc networks:

A pioneering approach to deal with the problem of traffic congestion using the characteristics of VANETs was proposed by BrijeshKadriet al. [13] that used the Adaptive Proportional Integral (PI) rate controller, a congestion control technique, intended for the Internet, to deal with the problem of vehicle traffic congestion in vehicular networks. They proposed that the adaptive PI rate controller is a potential algorithm to deal with the problem of vehicle traffic congestion as seen when the traffic volume exceeds the road capacity. In practice, the average waiting time could be calculated using the information provided by the algorithm and some intelligence that can calculate the current number of vehicles waiting to use the road segment. Using VANETs, this information can be transmitted to prospective drivers before they reach the intersection in order to assist them to choose a congestion free route. Using this algorithm, if all the routes ahead are congested, waiting for a free route may cause congestion in that particular lane too and consequently no further information regarding choice of route would be able to propagate.

An Optimal Strategy: Interplay Between TVWS and DSRC for QoS of Safety Message Dissemination

For vehicular communications, Dedicated Short-Range Communication (DSRC), the de facto standard, has normally been used. However, the one-hop transmission range of the DSRC is so short that a multi-hop dissemination is required in order to cover a large dissemination area of ESM. The multi-hop dissemination with the limited number of DSRC channels induces channel collision and network congestion. Moreover, the coexistence with PBMs aggravates collision and congestion of DSRC channels, which makes it hard to satisfy the requirements of the ESM dissemination. To overcome the limitation of the DSRC, [1] utilize an extra TV White Space (TVWS) band that has a large communication range for ESM disseminations, and exploit a DSRC band as a control channel for TV channel rendezvous.

Jae-Han Lim et al. [1] proposed and analyzed a distributed channel usage scheme between DSRC and TVWS bands for quality of service (QoS) of ESM disseminations under the existence of PBMs. The scheme employs TVWS Channel Rendezvous Algorithm (TCRA) that is based on available TVWS channel map, ensuring that vehicles within a dissemination area select the same channel with the ESM sender. To compensate ESM reception failures in a TVWS band, the scheme adopts On-Demand Recovery Algorithm (ODRA) that uses a DSRC band for an ESM retransmission to reception failure vehicles.

Distributed Beacon Frequency Control Algorithm for VANETs (DBFC):

LvHumeng et al. [6], proposed an adaptive congestion control scheme which adjusts the beacon transmission frequency according to the current network condition, while considering the appropriate accuracy of status information updating. It adaptively adjusts the frequency of beacon messages in two stages, which correspond to the dynamic vehicular environment. [6] analyzed it theoretically and experimentally. The algorithm detects and estimates the network load and controls the frequency of outgoing periodic beacons according to the environment. In particular, the method of half the frequency every time was adopted to effectively deal with the congestion caused by periodic messages.

A Markov Chain Based Model for Congestion Control in VANETs

M. A. Benatia et al. [2], proposed a novel Markov chain model that consists of four steps, namely, priority assignment, buffer monitoring,congestion detection phase, and beacon transmission rate adjustment to facilitate emergency packets propagation. The model responds to congestion in a proactive manner, and hence, minimizes the loss rate of safety messages due to the proactive nature of the algorithm.

Performance Evaluation of Beacon Congestion Control Algorithms for VANETs:

Long Le et al. [7], considered three beacon congestion control algorithms: rate control, power control, and joint power+rate control. Each of these algorithms incorporates the following three aspects. First, they observe the channel conditions during the monitoring interval T. Second, they derive the estimated channel load from the observed channel conditions. Third, they adjust the transmit power and/or the beacon rate to be used in the next monitoring interval.

Power-control-based Broadcast Scheme for Emergency Messages in VANETs:

Liqi Wei et al. [8], proposed a power-control broadcast scheme based on studying the IEEE 802.11p and IEEE 1609 WAVE standards for vehicular communications. Transmission strategy is adjusted based on vehicles' situation and the receive power of recently broadcastpacket from a sender node, and re-dissemination power in short-range for reliable broadcast is adapted based on the observed channel status.

The algorithm [8] uses selected boundary nodes to relay data avoiding broadcast storm problems in the highway scenario. Also, to ensure reliable transmission, two algorithms are executed simultaneously, Forward---Fast dissemination and Backward---Retransmisssion for reliable 1-hop broadcast of safety messages.

Application-Based Congestion Control Policy for the Communication Channel in VANETs:

Miguel Sepulcre et al. [12] proposed a novel proactive congestion control policy for vehicular ad-hoc networks, in which every vehicle's communication parameters are adapted based on their individual application requirements. Irrespective of other approaches, where transmission resources are likely to be assigned based on system-level performance metrics, the technique proposed in this research aims to individually satisfy the target application performance of each vehicle, while globally minimizing the channel load to prevent channel congestion.

Reducing Traffic Jams via VANETs:

A strategy to reduce traffic congestion with the help of periodically emitted beacons to analyze traffic flow and to warn other drivers of a possible traffic breakdown is illustrated by Florian Knorr et al. [3]. Under this scheme, drivers who receive such a warning are informed to keep a larger gap to their precursor so that they are less likely to be the source of perturbations, which can cause a traffic breakdown. However, this work does not pay attention to prioritizing event driven messages above beacon messages.

V. Overview Of Functions, Parameters And Characteristics Of Congestion Control Algorithms

A comparative analyze of functions, characteristics and parameters of some of the existing algorithms are overviewed in table 1.

Sr. No.	Algorithm	Parameter	Function	Attributes
1.	Utility-Based Congestion Control and Packet Forwarding in VANETs	Data rate based	The algorithm uses an application-specific utility function and encodes the quantitative utility information in each transmitted data packet. A decentralized algorithm then calculates the "average utility value" of each individual node based on the utility of its data packets and assigns a share of the available data rate proportional to the relative priority.	1.Avoids the typical starvation of some nodes in the network. 2. Increases the efficiency of information dissemination and fairness. 3. Combination of broadcast data transmission and SAFE application is used.
2.	Cooperative Collision Warning Using Dedicated Short Range Wireless Communication	Cooperative Collision Warning	Periodic broadcasting of short messages for the purpose of driver situational awareness and warning via vehicles.	1.Two design issues are explored; performance trends with distance and potential avenues for broadcast enhancements. 2.Vehicles alert drivers of impending threats without expensive equipment. 3.Employs DGPS instead of ordinary GPS receiver to increase the range of the sensor. 4.Introduces a novel latency metric that reflects the critical role played by successive packet collisions in degrading the performance of periodic safety applications.
3.	Dynamic priorities-based Congestion Control scheme	Prioritizing messages based	Messages priorities are dynamically evaluated according to their types, the network context and the neighborhood.	1. Priorities are assigned based on two factors; a. Static Factor: deduced from application type and consist of five priorities levels, namely, $PRI_{Emergency}$, PRI_{VANET}, PRI_{HIGH}, PRI_{MID}, and PRI_{LOW}. b. Dynamic Factor: realized from specific network context and depends on two considerations, namely, Node Speed and Message Utility Consideration. 2. Low priority message transmission is

				freezed in order to send high priority packets with minimum delay.
4.	Congestion Control to Achieve Optimal Broadcast Efficiency in VANETs	Transmission power based	The algorithm provides a congestion control and power control strategies to achieve optimal broadcast efficiency under the Rayleigh fading channel.	1. Provides power control policy in VANET as node density varies. 2. Presents a complete characterization of the optimal transmission probability as a function of node density, transmission power, packet length and other VANET system parameters. 3. Offers a worst-case guaranteed congestion control strategy that achieves over 95% of the optimal performance even when the bounds on the node density differ by an order of magnitude.
5.	Congestion Control approach for Event-Driven Messages in VANETs	Prioritizing messages based	The algorithm focuses on uni-priority of event-driven messages so that these messages along with the nodes with the same high priority packets can be scheduled before starting the transmission process to ensure timely and reliable delivery of event-driven safety messages.	1. Features weaknesses and advantages of some congestion control algorithms to assist researchers to tackle the inherent problems of congestions in VANETs. 2. Provides an overview of some of the congestion detection methods, namely, Event-Driven Detection Method, Measurement-Based Detection Method and MAC Blocking Detection Method.
6.	Efficient Congestion Control in VANET for Safety Messaging	Transmission Rate and Transmission Power.	The algorithm provides a conceptual view of a congestion control scheme using transmission rate and transmission power control techniques simultaneously for optimal congestion control within VANETs.	1. The algorithm reveals that only power control techniques do not satisfy the requirements of envisioned beacon-dependent safety applications and also methods used for measuring channel usage level in transmission rate control technique may not be as effective under real world conditions. 2. The algorithm offers a congestion mitigation process to decide appropriate technique to be used i.e. adjusting transmission power or message transmission.
7.	A Congestion Control Scheme for Fast and Reliable Dissemination of SafetyMessages	Priority assignment and Transmission power & rate adjustment	The algorithm consist of three phases; priority assignment to themessages to be forwarded, congestion detection phase, and finally transmit power and beacon transmission rate adjustment to facilitate emergency messages spread within VANETs.	1. It doesn't alter the performance of the running ITS applications unless a VANET congestion state is detected. 2. It ensures that the most critical and nearest dangers are advertised prior to the farther and less damaging events. 3. Three priorities level are defined; high, medium and low level.
8.	Adaptive Proportional Integral rate controller congestion control algorithm	Adaptive Proportional Integral rate controller (Control Theory)	Adaptive Proportional Integral rate controller congestion control technique, intended for the Internet, deals with the problem of vehicle traffic congestion in vehicular networks.	1. This is a potential algorithm to deal with the problem of vehicle traffic congestion as seen when the traffic volume exceeds the road capacity. 2. The information evaluated can be transmitted to prospective drivers before they reach the intersection in order to assist them to choose a congestion free route.
9.	Application-Based Congestion Control Policy for the Communication Channel in VANETs	Vehicle's Communication parameter depending upon D_w i.e. Warning Distance.	The algorithm aims to individually satisfy the target application performance of each vehicle, while globally minimizing the channel load to prevent channel congestion.	1. The algorithm takes into account lane change assistance application.
10.	Reducing Traffic Jams Algorithm	Vehicle to Vehicle Communication	The algorithm make use of periodically emitted beacons to analyze traffic flow and to warn other drivers of a possible traffic breakdown.	1. Drivers who receives warning are informed to keep a larger gap to their precursor so that they are less likely to be the source of perturbations, which can cause a traffic breakdown.
11.	A Markov Chain Based Model for Congestion Control	Markovian model based transmission rate control	A novel Markov chain model that consists of four steps: priority assignment, buffer monitoring,congestion detection phase, and beacon transmission rate adjustment to facilitate emergency packets propagation.	1. The model responds to congestion in a proactive manner. 2. Minimizes the loss rate of safety messages due to proactive nature.
12.	An Optimal Strategy: Interplay Between TVWS and DSRC for QoS of	Interplay Between TVWS and DSRC	The algorithm proposes adistributed channel usage scheme between DSRC andTVWS bands for quality of service (QoS) of ESM disseminationsunder the existence of PBMs.	1. To overcome the limitation of the DSRC, the algorithm utilize an extra TV White Space (TVWS) band that has a large communication range for ESM disseminations, and exploit a DSRC band as a control channel for TV

	Safety Message Dissemination			channel rendezvous. 2. The scheme employs TVWS Channel Rendezvous Algorithm (TCRA) that is based on available TVWS channel map, ensuring that vehicles within a dissemination area select the same channel with the ESM sender. 3. To compensate ESM reception failures in a TVWS band, the scheme adopts On-Demand Recovery Algorithm (ODRA) that uses a DSRC band for an ESM retransmission to reception failure vehicles.
13.	Distributed Beacon Frequency Control Algorithm for VANETs (DBFC)	Beacon frequency control	An adaptive congestion control schemewhich adjusts the beacon transmission frequency according tothe current network condition, while considering theappropriate accuracy of status information updating.	1. Estimates the network load and controls the frequency of outgoing periodic beacons according to the environment. 2. The method of half the frequency every time is adopted to effectively deal with the congestion caused by periodic messages.
14.	Power-control-based Broadcast Scheme for Emergency Messages in VANETs	Selects boundary nodes to relay data	Transmission strategy is adjusted based onvehicles' situation and the receive power of recently broadcastpacket from a sender node, and re-dissemination power inshort-range for reliable broadcast is adapted based on theobserved channel status.	1. Uses selected boundary nodes to relay data avoiding broadcast storm problems in the highway scenario 2. To ensure reliable transmission, two algorithms are executed simultaneously, • Forward---Fast dissemination • Backward---Retransmisssion for reliable 1-hop broadcast.
15.	Performance Evaluation of Beacon Congestion Control Algorithms for VANETs	Transmit rate and/or transmit power control	Considers three beacon congestion control algorithmsthat control the beacon load below a certain threshold byadjusting the transmit rate and/or transmit power for the beaconmessages.	1. Rate control is adequate when all nodes use the same transmit power and it is possible to adjust the beacon rate without violating the applications' requirements. 2. Power control is appropriate when all nodes' beacon rate is constant and the communication ranges corresponding to the varying transmit power meet the applications' requirements. 3. Power+rate control is the mostflexible algorithm because it allows application designer to trade off between beacon rate and beacon transmit power.

Table 1. Function, parameters and characteristics of Congestion Control Algorithms

VI. Conclusion

This paper focuses on congestion control issue within VANETs. It provides an analytical view to some of the proposed congestion control algorithm in recent yearsalongwith an overview to DSRC standards for VANETs.The presented compilation can be accounted as groundwork to the study of congestion control schemes for VANETs. The challengesemphasized in this study can be considered as future work by researchers to develop an algorithm to control congestion within VANETs in order to utilize network resources efficiently in various circumstances.

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