An Approach to Control Congestion Using Vanets (Vehicular Adhoc Network)

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Abstract: ***Vehicular Ad hoc Networks (VANET) plays an important role in future car to car communication systems and related applications like Self Organizing Traffic Information System. Congestion control for VANETs has not been studied thoroughly so far – but this feature will be extremely necessary for VANET applications and network performance. To cope up with the issue, the paper presents a transmission power based congestion control algorithm. The results are simulated using ns-2 in two different scenario, namely, city and highway scenario.***

Keywords: VANETs, DSRC, Congestion control, transmission power

1. Introduction

Congestion control is a challenging issue within VANETs (vehicular ad hoc networks). Vehicular ad hoc networks (VANET) are a form of MANETs used for communication among vehicles and between vehicles and roadside equipment. VANET bring new challenges to achieve safe communication architecture within such environment. VANETs are distinguished from other wireless networks by their specific characteristics such as; predictable vehicles movement and high speed, powerful processing units, large storage capacities and new applications scenarios.

A large number of comfort and safety applications can be implemented based on VANETs; a popular example are traffic information systems, e.g. the Self Organizing Traffic Information System: In these systems, the vehicles act directly as a sensor which measures the traffic condition at their current location. This information is analyzed and disseminated within the VANET in a large area and allows each vehicle to keep track of the local traffic situation.

The paper is structured as follows: Section II provides a brief review of literature, Section III gives an overview to the proposed congestion control algorithm, Section IV provides the simulation results & Section V concludes the paper.

2. Literature Review

L. Wischhof et al. [15] 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 [15], 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.

To evaluate the role of neighborhood in VANETS, Stibor et al. [10] approximates the neighborhood nature of VANETs within a four highway lanes context (two lanes for each direction). Their simulations and analysis shows 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.

Tamer ElBatt et al. [12], 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 [12]. 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.

Mohamed Salah et al. [9], 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 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. [4]. 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.

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. [5] 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.

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 BilalMunirMughal et al. [6]. 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.

Assigning uni-priority for event-driven messages to secure life is proposed by MohamadYusof Doris et al. [3]. They summarized the weaknesses and advantages of some congestion control algorithms to assist researchers to tackle the inherent problems of congestions in VANETs.

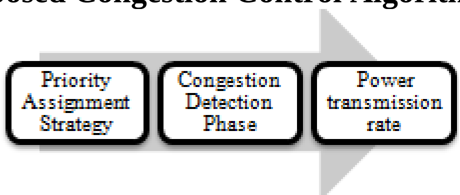
The periodic beacon broadcast consumes a large part of the available bandwidth leading to an escalating number of collisions among MAC frames, particularly in case of high vehicular density. This severely affect the performance of the ITS safety based applications that require timely and reliable dissemination of the event-driven warning messages. To deal with this dilemma, SoufieneDjahel et al. [2] 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.

A pioneering approach to deal with the problem of traffic congestion using the characteristics of VANETs was proposed by Brijesh Kadri et al. [8] 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.

Miguel Sepulcre et al. [7] 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.

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 FlorianKnorr et al. [1]. 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.

3. Proposed Congestion Control Algorithm



Block Diagram of Congestion Control Algorithm

(a)Priority assignment and messages scheduling

- *Immediate danger notification (emergency message):* this type of messages is sent in case of accidents, very bad weather condition such as snow, fog etc. It is assigned the Higher Level (*HL*) priority.

- *Warning message:* sent to advertise an important event on the road but not an immediate (critical) danger. It is assigned an intermediate or Medium Level (*ML*) priority.
- *Driving information announcement:* such as information about traffic jams in some road segments to direct the driver to the fastest and least congested road. It is assigned the Lowest Level (*LL*) priority.

For messages with same priority, a slight modification of the message header is done. This is to speed up the transmission of the fresh emergency messages at the expense of the old messages or those advertising a farther danger. This choice is due to the following reasons:

- A lower *Hopcptvalue* means that the danger is very close to the receiver vehicle. Thus, this message needs to be transmitted very fast towards its neighbors to prevent more damage.
- A larger *Hopcptvalue* indicates that the danger is relatively far from the receiver vehicle. Therefore, delaying its transmission is less harmful than the previous type of messages.

(b)**Congestion Detection mechanism**

A set of metrics that represents VANET state at any point of time to detect whether congestion has occurred or not is given as follows [1]:

- *Average Waiting Time (AWT):* to access the wireless medium (particularly the CCH), which can be also inferred from the Medium Busy Time (MBT).
- *Collision Rate (CR):* this metric is defined as the ratio of the unsuccessful transmissions from the vehicle to the total number of sent packets over CCH.

$$CR(V) = \frac{Own\,unsuccessful\,transmission}{\sum sent\,message\,over\,CCH} \quad (2)$$

- *Beacon Reception Rate (BRR):* that is expressed as the ratio of the number of received beacons, issued from different vehicles, to the total number of received beacons [1].

$$BRR(V) = \frac{|N_{1hop}(V)|}{\sum Beacons_{received(V)}} \quad (3)$$

Each vehicle collects and updates the information regarding the above three metrics that express the state of VANETs in terms of traffic load, at each Congestion Monitoring Interval (*CMI*). This interval is divided into a set of equal length mini-intervals [1]. During each mini interval one measurement is taken regarding the above metrics and the corresponding values are stored in a three dimensions vector called Congestion Index Vector (*CIV)*

$$CIV_i = (AWT_i; CR_i; BRR_i) \quad (4)$$

To calculate the mean vector *CIV* following the formula given below [1]:

$$\overline{CIV} = \frac{\sum_{i=1}^{M} CIV_i}{M} \quad (5)$$

Subsequently, we calculate the distance between the *CIV* measured during a given *CMI* and the *CIV* as follows:

$$\text{Dist}(CIV) = \|CIV - CIV\|^2 \quad (6)$$

Finally, the congestion is detected if the distance is larger than a certain threshold *Thr*, as indicated in Equation

$$\text{Dist(CIV)} > \text{Thr VANET state is congested}$$
$$\text{Dist(CIV)} \leq \text{Thr VANET state is nomal} \quad (7)$$

(c)Transmission Power adjustment

Calculate the transmit power that the vehicle will use for subsequent transmissions according to the following equation [1].

$$P = MAX[min(Txpw(i); Txpw(own)); P(nfdist+)] \quad (8)$$

Where represents the difference between the next forwarder distance (*nfdist*) and the maximum distance (*maxdist*) separating one candidate to the vehicle. If *maxdist*is smaller than *nfdist*then is set to 0. Notice that the value *i*refers to the $vehicle_{id}$and *P*(*nfdist+*) can be interpreted as the transmit power that ensures a transmission range slightly greater than *nfdist+* .

First, we calculate the increase factor (*IF*) according to the formula below.

$$IF = \frac{|(N_{1hop} \cup N_{old}) - (N_{1hop} \cap N_{old})|}{|N_{1hop}|} \quad (9)$$

Secondly, we adjust the transmit power *P* according to the *IF* value as described the following [1];

$$P1 = \begin{cases} P & if\ IF = 0 \\ P(1 + (1 - MIN(IF, BRR))) & if\ 0 < IF \leq 1 and\ CR\ is\ low \\ P(1 + (\frac{(IF-1)}{IF} * CR)) & if\ 0 < IF \leq 1 and\ CR\ is\ high \\ P(1 + (\frac{(IF-1)}{IF})) & otherwise \end{cases} \quad (10)$$

Finally, the transmit power level to be used for transmission is the minimum of the intermediate value *P*1 and the current transmit power [1].

$$P = MIN\,[Txpw(i); P1] \quad (11)$$

4. Simulation

The section provides the simulation results of the proposed congestion control algorithm. Table 1. shows the various parameters consideration for the simulation.

Table 1: Parameter Consideration

Parameters	Value
Physical layer	OFDM
Topography dimensions (X,Y)	1500, 1500
Frequency Band	5.9Ghz
Beacon transmission rate	Every 100ms
Transmission range	250m
Vehicles Density	10-100veh/km/lane
Data Rate	3 mbps
Simulation Time	10sec

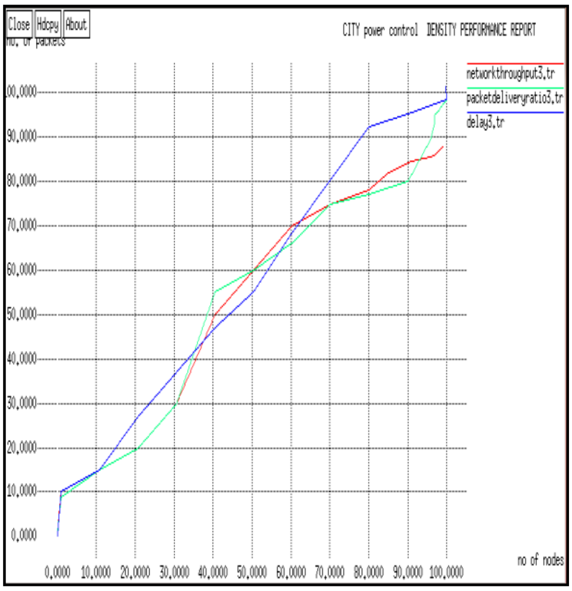


Figure 1: CITY SCENARIO: With Applying Congestion Control Algorithm

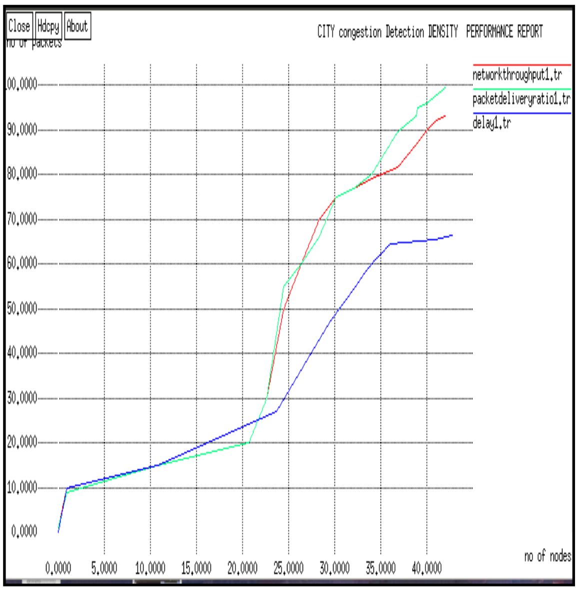


Figure 2: CITY SCENARIO: Without Applying Congestion Control Algorithm

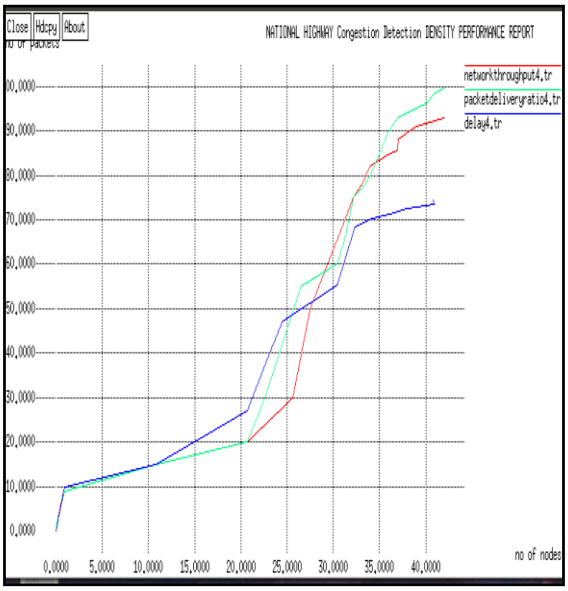


Figure 3: HIGHWAY SCENARIO: Without Applying Congestion Control Algorithm

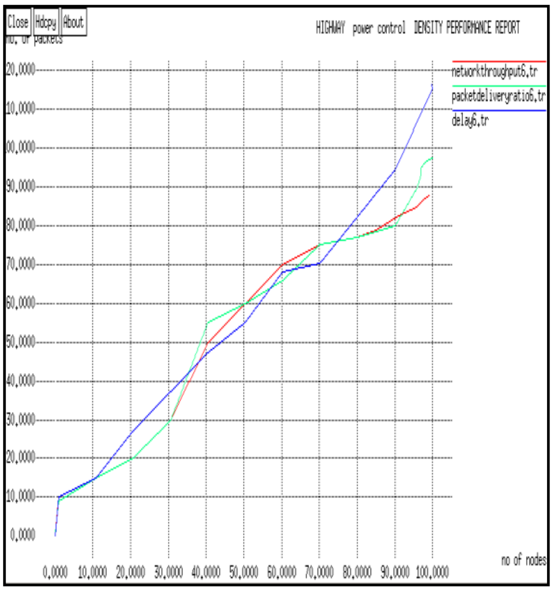


Figure 4: HIGHWAY SCENARIO: With Applying Congestion Control Algorithm

5. Conclusion& Comparison

We conclude that while applying the power control algorithm the network performance upgrades, throughput increases, delay decreases and packet delivery ratio increases. Comparison b/w the two scenario: city and highway is given below in Table [2]

Sr.no.	*Algorithm*	*Results*	
		City Scenario	*Highway Scenario*
1.	Without Applying any algorithm	Network performance starts degrading slightly after 30 vehicles/km/lane as the network starts getting congested.	Network performance starts degrading with increase in vehicular density as no congestion control scheme is applied to the network i.e., after 30V vehicle/km/lane.
2.	With power control algorithm	i. Performance is considerably improved. ii. Network delay is slightly increased due to path preference priority assignment. iii. Shows minor degradation in performance due to increase in density after 65 vehicles/km/lane.	i. Performance is significantly improved after applying power control algorithm. ii. Comparatively low delay due to path preference strategy. iii. Shows trivial degradation in performance due to increase in vehicular density after 75vehicles/km/lane

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