Review on Congestion Control Algorithm for VANET

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ABSTRACT
Vehicular ad hoc networks (VANETs), which is a subclass of Mobile ad hoc networks, have recently been developed as a standard means of communication among moving vehicles because it has tremendous potential to improve vehicle and road safety, traffic efficiency. VANET applications has the characteristics such as fast change of topology, bandwidth limitation and lack of central coordinationn that causes network congestion which restricts the network performance. Number of solutions proposed to overcome these challenges and to reduce congestion on VANET. These solutions include congestion control algorithms, some of them based on maintaining the beacon load below certain threshold value by adjusting transmit power or transmit rate or both. And others are based on utility function, carrier sense threshold, prioritization or a combination of them. Hence, this study takes a closer look at existing congestion control algorithms to solve congestion problems because it affects the performance of safety messages. The study further exposes the weaknesses and advantages of some of these congestion control algorithms, which can be helpful to tackle with the problems of congestions in VANETs.

General Terms
Algorithms

Keywords
VANET, Beacon messages, Event driven messages, Congestion control, IEEE 802.11p

1. INTRODUCTION
The networks with the absence of any centralized or pre-established infrastructure like access points in managed wireless networks or routers in wired networks called Ad hoc networks [8]. Such wireless ad hoc networks can be categorized via their application, such as Wireless Mesh Networks (WMN), Mobile Ad Hoc Networks (MANET) Wireless Sensor Networks (WSN), and Vehicular Ad hoc Networks (VANETs). VANET is a particular type of MANET, that vehicles play the role of nodes in it. As opposed to MANET, vehicles move on predefined roads and velocity depends on the speed signs. Considering providing comfort and safety to the road users, VANET regarded as one of the influencing areas in advancement of the intelligent Transportation System (ITS).

The basic target of VANET is to increase safety of the road users and comfort of the passengers. There are many challenges in VANET that have to be resolved to offer reliable services such as routing, security, and quality of service. Due to many issues such as Inaccurate State of Information, dynamically Varying Network Topology, Absence of Central Coordination, Hidden Terminal Problem, Limited Resource Availability Error Prone Shared Radio Channel, and Insecure Medium, therefore, supporting Quality of Service (QoS) is a challenging task. Many approaches proposed to improve the QoS in VANETs. For providing better QoS, congestion control algorithms are widely used. There are two types of messages to enable safety applications. On the one hand, cooperative awareness messages (CAMs), also known as beacons, broadcasted periodically by all nodes on the control channel, in order to receive and provide status information on presence, geographical position and movement of neighboring nodes, and service announcements to/from those nodes. On the other hand, emergency event-driven messages transmitted when it notice abnormal or hazardous condition, in order to inform surrounding nodes about it. [7] The challenge regarding this beaconing activity will be to control the load in the channel in order to stay away from channel congestion. Congestion control achieve by making efficient use of available channel bandwidth

VANET belongs to wireless communication networks area. The Federal Communication Commission (FCC) allocates the frequency spectrum for VANET's wireless communication. Then the Commission in 2003 established the Dedicated Short Range Communications (DSRC) Service. The DSRC is a communication service, which utilizes for public and private safety and uses the frequency range of 5.850-5.925 GHz [1]. The DSRC designed in multi-channel system. The FCC divided the DSRC spectrum into seven channels so that each of them has 10 MHz bandwidth. Six of them identified as Service Channels (SCH), and one of them then identified as the Control Channel (CCH), as shown in Fig. 1. The CCH channel is used for safety messages, while SCH channels are used for non-safety as well as WAVE-mode messages or services [3]

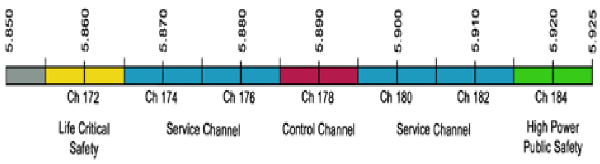

Figure1. DSRC channels

In high traffic, a large number of vehicles broadcast beacon messages at a high frequency, which can easily congest the CCH channel. The periodic messages are broadcast may lead to broadcast storm flooding problem in VANETs. It is very important to keep the CCH channel free from congestion in order to ensure timely and reliable delivery of event-driven safety messages In order to avoid congestion of CCH channel and delay of event-driven safety message, a reliable and efficient congestion control algorithm is needed.[4]

This paper gives the detailed study of various congestion control schemes and reveals the advantages and disadvantages of them. It does thorough analysis of the parameters, which affect congestion.

2. PARAMETERS AFFECTING CONGESTION

Based on number of researches, various parameters, which affect congestion, analyzed and the tread off between them derived. The parameters that directly affect the channel congestion are termed as primary parameters such as transmit power, transmit rate and beacon frequency; whereas the derived parameters depend on the primary parameters, which are fairness, prioritization, and utility function.

2.1 Transmit Power

Transmit power is defined as power content of each node. With transmit power control; beacon reception rate decreases hence event driven reception increases. This further reduces channel busy time and results in the congestion reduction.[1]

2.2 Transmit Rate

It is defined as the rate at which packets are transmitted over the channel. With transmit rate control, event driven probability is increased this reduces CBT and reduces channel congestion. [1]

2.3 Beacon Frequency

Beacon frequency is the number of beacon messages transmitted by a node per unit time. In dense network beacon frequency reduces; as density decreases, the beacon frequency increases. This frequency control results in improvement of beacon reception probability this reduces channel load and hence channel congestion. [5]

2.4 Fairness

Fairness deals with providing fair portion of available resources to each node so that it can get equal opportunity over channel. Fairness maximizes the minimum transmit power, it increases individual coverage and hence road safety.

2.5 Prioritization

Prioritization means assigning more priority to event driven messages than beacon message, this increases safety and reduces congestion.

2.6 Utility Function

The utility function used to determine utility of transmitting data packet of a particular application at current point in time. The application specific utility function calculated for each packet and encoded in packet header for estimating utility of individual data packet at each node .based on estimated utility of data packets. Each node adapts its own data rate. In case of congestion, it drops lower utility packets.

2.7 Node Density

VANET is affected by characteristics of traffic flow. Vehicle (node) density influences average speed of node and thus affecting network mobility. In general, when node density increases; it increases the packet transmission rate, which ultimately increases channel load and results in congested channel. This parameter generally use for simulation and analysis purpose.

We analyzed these parameters thoroughly in following section with the help on different congestion control algorithms. These algorithms along with one can use different congestion detection methods or more parameters mentioned above.

3. CONGESTION CONTROL ALGORITHMS IN VANET

In VANET, number of researches has proposed to control the congestion on channel by considering various factors such as power, rate, bandwidth, utility function. All these algorithms reduce the congestion by adjusting the channel load below certain value.

3.1 Beacon Congestion Control Algorithm

Beacon congestion control algorithm based on concept of periodic beacon and event driven messages. When congestion occurs, it is necessary to reduce the beacon load to keep a certain amount of the available bandwidth for the event-driven messages because they carry time-critical information of high importance. The beacon load is kept below a certain threshold by adjusting the transmit rate and/or transmit power for the beacon messages. Each node executes congestion control algorithm independently and uses channel busy time (CBT) as metric for estimated channel load.

The rate control approach executed assuming that all nodes use same value transmits power such that the aggregated beacon load is below threshold value CBT, by achieving fairness. The beacon rate at node i derived from aggregated beacon load at node i and beacon rate for an arbitrary node i

$$P\iota\,(\tau) = \frac{\text{CBT Th}}{CBTPER,i(t-1)} \cdot RAVG(t-1)$$

Whereas power control scheme assumes all nodes use, constant rate R. the assumption is made for practical purpose that CS and CR range is constant. The maximum $CR_{MAX,I}$ is approximated using CS range. The value of CR_{MAX} is used by node I to select its beacon transmit power level such that the corresponding CR range is below $CR_{MAX.}$

$$\Pi\iota(\tau) = MA\Xi[XP_{[\Pi]} < XP_{MA\Xi,\iota}], \Pi \square [\Pi_{MIN,\square\,\square..}, \Pi_{MA\Xi}]$$

The combined power and rate control scheme calculates the maximum transmit rate at different transmit power level by estimating node density value.

$$\text{RMAX}\,[p] = \frac{\text{CBTTH}}{2 \cdot \text{CR}[P] \cdot \text{D} \cdot \Delta} \cdot \frac{\text{C}}{\text{PSIZE}}$$

This research has analyzed the effect of all mentioned algorithms on reception rate of beacon and event driven message and CBT, and reveals better performance of these algorithm in improving reception rate of event driven message but at the cost of reduced beacon reception rate.[1]

3.2 Distributed Fair Transmit Power Algorithm for VANET (DFPAV)

Distributed Fair Transmit Power Algorithm for VANET (DFPAV) proposed that the optimization criterion for improving safety built upon the concept of Fairness. This mean to make safety applications capable of detecting an unsafe situation and taking the right decisions to avoid a danger in case of emergency, it is very important that every vehicle has a good estimation of the state of all vehicles in its closer surrounding. In other words, if a vehicle does not assign a fair portion of the resources, it cannot announce itself to its closer neighbors, and becomes a danger itself. Thus, the available channel capacity must share among nodes in a fair way. This is need for maintaining relevance of safety messages, balancing event driven messages, keeping beacon load below maximum beacon limit. Distributed fair transmit power adjustment scheme uses FPAV algorithm for computing power. It helps to solve BMMTxP problem maximizing the minimum power used by nodes and maintaining network load below MBL.

Algorithm D-FPAV:

(algorithm for node ui)

INPUT: status of all the nodes in CSMAX(i)

OUTPUT: a power setting PA(i) for node ui, such that

the resulting power assignment is an optimal

solution to BMMTxP

1. Based on the status of the nodes in CSMAX(i),

compute the maximum common tx power level

Pi s.t. the MBL threshold is not violated at any

node in CSMAX(i)

2a.Broadcast Pi to all nodes in CSMAX(i)

2b. Receive the messages with the power level from

nodes uj such that ui ∈ CSMAX(j); store the

received values in Pj

3. Compute the final power level:

PA(i) = min_Pi, minj:ui∈CSMAX(j){Pj}

This algorithm is summarizes as below, node u_i collects information about all nodes, within its CS range at maximum power. Common power level computed using FPAV algorithm power value. This computed value of power then sent to all nodes in CS range. If node u_i receives information from node uj such that uj belongs to CS range of ui then final value of power level is calculated. To improve the efficiency, this information piggybacked in beacon message. This distributes fair amount of power between each node that results in reducing channel busy time by 57% and probability of receiving event driven message is increased up to 110%.[2]

3.3 Dynamic DFPAV

Dynamic DFPAV focuses on the different approaches of congestion control mechanism. The congestion control mechanisms broadly divided into three basic approaches proactive, reactive and hybrid. Proactive model deals with the estimation of transmission parameters based on number of nodes in vicinity, which can achieve fairness and prioritization; reactive approach uses first order feedback regards to the desired result about congestion status and decides whether and how the action should carried out and hybrid approach combines the advantages of both proactive and reactive. The same DFPAV algorithm mentioned above used for power assignment but assigns dynamic MBL value instead of fixed value. Dynamic MBL value assigned using following procedure considering traffic and non-traffic condition for street and event driven and non-event driven for messages. Based on these, four states are formed which are helpful for dynamic MBL assignment.

Procedure: find Traffic (for node ui)

According to the status of the nodes in CSMAX (i) and neighbor table of ui

Compute the neighbor vehicle speed

If 80% of neighbor vehicles' speed < 30km/h

Then there is traffic in the highway (street) and return true

Else return false

Procedure: dynamic MBL (for node ui)

If find Traffic = true

Piggyback the information every 15 beacons

Return MBL = *Bandwidth/3*

If find Traffic = false and no event-driven

Piggyback the information every 10 beacons

Return MBL = *Bandwidth*

If find Traffic = false and event-driven

Piggyback the information every 10 beacons

Return MBL = *2*Bandwidth/3*

D-DFPAV adjusts the transmission power depending upon application layer traffic, achieves fairness and prioritization by assigning dynamic MBL values. Dynamic DFPAV is more effective than fixed DFPAV, which gives better throughput and reception probability [3]

3.4 Congestion Control Algorithm in VANET

Congestion control algorithm in VANET aims high reliability and timely delivery of event driven message. In high traffic, large number of vehicles broadcasts beacon safety messages at high frequency and event driven messages are sent multiple times ;the control channel will easily congested. This situation will decrease throughput and increase delay significantly. The congestion control algorithm can ensure high reliability and timely delivery of safety messages. The algorithm comprise of two main parts i.e. event driven detection and measurement based detection.

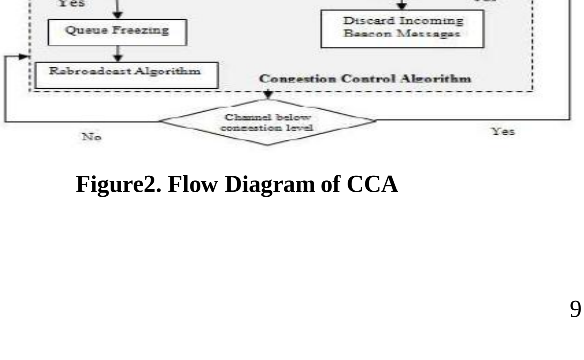

Figure2. Flow Diagram of CCA

The control channel monitored on packet queue basis and if number of messages exceeds certain threshold value, the beacon messages discarded and monitor event driven messages.When it appears, the queue freezing method applied on all transmission queues except event driven messages so that they should delivered with minimum delay.

The effect of this technique is tested in different vehicle density; it provides an efficient method for delivering event driven safety message in high density, good results for packet delay ratio.[4]

3.5 Distributed Beacon Frequency Control Algorithm for VANETs (DBFC)

Distributed Beacon Frequency Control algorithm for VANETs (DBFC) implies that the beacon load should be reduced to improve channel condition, this can be done by adjusting transmit parameters such as frequency. An adaptive congestion control scheme proposed which adjusts the beacon transmission frequency according to the current network condition, while considering the appropriate accuracy of status information updating. Based on the number of neighbor nodes, the traffic density decided and accordingly beacon frequency is adjusted between maximum and minimum value.

Algorithm : Distributed Beacon Frequency Control
algorithm
Input: N,PS , vi, F
Output: fParameter limitation : F, f ∈[f min, f max]

```
if N > Ndense
if( PS < pdelivery and vi < vthreshold )
{
f = 0.5F
if ( f < f min )
f = f min
}
else
If( PS < pdelivery and vi ≥ vthreshold )
{
f = f +λ
If ( f > f max )
f = f max
}
Set beacon frequency to f and add the F into the
            Beacons
```

Compared with fixed frequency value, this scheme is more effective in reducing the channel load with improved beacon reception probability [5].

3.6 Utility based Packet Forwarding and Congestion Control (UBPFCC) Algorithm

Utility Based Packet Forwarding And Congestion Control (UBPFCC) algorithm is based on concept of utility-based congestion control for VANETs. The control algorithm uses 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 local environment. The utility function given as

$$Y_{T\Xi}(\pi) = \frac{\text{"updated segment value"}}{\text{"total number of segment value"}}$$

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. When congestion occurs, a packet with lower utility drops and congestion reduces. [6]

3.7 Efficient Congestion Control in VANET (Hybrid Approach)

Efficient congestion control in VANET (Hybrid Approach) supports the use of transmission rate along with transmission power adjustment to increase beaconing range to maximum level to increase road safety based on beaconing applications. This scheme proposes an effective approach of efficiently managing transmission rate and power to control channel congestion. Flowchart below gives schematic of this approach in detail. All nodes need to inform about their channel condition. Whenever channel crosses saturation level, a node senses it immediately. With congested channel, congestion mitigation process starts. Depending upon current transmission rate and power, the congestion mitigation decides the appropriate technique. The process repeated until channel load gets below congestion level.

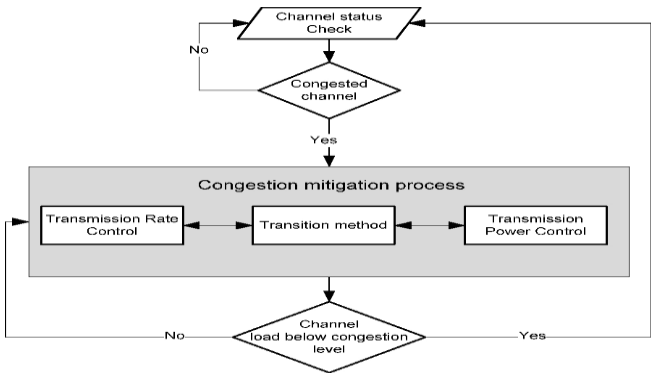

Figure 3. Flow Diagram of ECCA(Hybrid)

4. COMPARISON AND DISCUSSION

Table 1. Comparison Table

Approach	Ref.	Packet rate	Transmit power	Access priority	Carrier sense threshold	Packet delay	Simulator used
Power or Rate based	[1]	YES	YES	NO	YES	NO	NS-2
Power and rate	[1]	YES	YES	NO	YES	NO	NS-2
DFPAV	[2]	NO	YES	YES	YES	NO	NS-2

Application based CC	[5]	YES	YES	NO	NO	NO	NS-2
Dynamic DFPAV	[3]	YES	YES	YES	YES	NO	NS-2
FTPC	[6]	YES	YES	YES	YES	YES	NS-2
CC	[4]	NO	NO	YES	NO	YES	VEINS
Efficient CC	[9]	YES	YES	NO	YES	NO	NS-2

The above table explains the relation of different parameters with all the proposed congestion control algorithms.

5. CONCLUSION AND FUTURE WORK

In this paper, we tried to analyze various parameters affecting channel congestion with different congestion control algorithms thoroughly. Many of these algorithms [1, 2, 3] are based on power or rate control [5] considers beacon frequency as prime parameter. Some of them are base on combination of parameters. The algorithms [1, 2, 3, 4] are mainly focusing on event driven message reception by achieving fairness, prioritization. The concept in [5, 9] increases the beacon reception probability. The focus on event driven reception affects the reception of beacon messages and vice versa. This affects the level of safety in VANET. There needed to make balance between the receptions of both type of messages. Hence, tradeoff between parameters must be taken in to account for designing congestion control algorithm.

In future, we try to design congestion control scheme that will balance event driven and beacon reception rate such that it will enhance the road safety. We also plan to verify and evaluate performance of our proposed congestion control algorithm over different scenarios.

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