

Congestion Control Approach by Dynamically Adjusting the Load of Beacon Messages in VANET

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Abstract – The prime goal of Vehicular Ad hoc Network (VANET) is to provide life safety on the road. To achieve this, vehicles make use of two types of safety messages one is Periodic safety messages (beacons) to exchange status information e.g. position, speed etc. and second one is Event-driven messages to broadcast in case of an emergency situations e.g. accidents, hard-braking etc. The main objective of congestion control in VANET is to best exploit the available network resources while preventing sustained overloads of network nodes and links. Appropriate congestion control mechanisms are essential to provide efficient operation of a network. Ensuring congestion control within vehicular ad hoc networks faces special challenges, due to the specificities of such environment (high mobility of nodes, high rate of topology changes, high variability in nodes density and neighborhood configuration, broadcast communication nature, etc.). In this context, we present a congestion control approach, to ensure efficient bandwidth usage of control and service channel within VANET. It supports dynamically adjusting the load of beacon messages.

Index Terms – VANET, MBL, D-FPAV, V2V, V2I, SCH.

1. INTRODUCTION

Congestion control scheme in Vehicular Ad hoc Network (VANET) is to provide life safety on the road as well as comfort to the automotive users. Each vehicle in VANET is a node which is able to transmit its own message and can receive messages from other vehicles [7, 8, 9, 10]. To achieve this, vehicles make use of different types of messages. However, such system suffers from quality of service degradation for safety applications caused by the channel congestion in scenarios with high vehicle density.

In our proposed work, we assume that four different types of messages i.e., Emergency messages, Beacon messages, warning messages and query messages are used for communication in VANET. Each node maintains a control queue (CQ) to store the

safe messages and a service queue (SQ) to store the unsafe messages. The control channel (CCH) is used for the transmission of safe messages and service channel (SCH) is used for the transmission of unsafe messages [6]. But in high vehicle density the channel saturation can easily occur due to load caused by beacon message transmissions. These saturated channel conditions can lead to failure of reception of safety information.

Thus, we demonstrate a scheme to reduce the channel load and prevent the occurrence of congestion in the channels by adjusting the transmission parameters like transmission rate and transmission range which has an impact on the condition of channels. The values of these parameters are compared with predefined thresholds to make the decision about congestion occurrence. The predefined thresholds have a significant impact on the performance of networks for detecting the congestion. In [1], if the length of SCHs queue exceeds a threshold, it is considered that the congestion occurs in the network. Then, the detected node controls the congestion by decreasing the transmission rate.

Therefore, there is a scheme to set limit and control the load and congestion on the channel, since the exchange of beacon messages alone can saturate the channel. In [2], researchers defined MBL as a threshold of above-mentioned mechanism but they assumed that threshold of MBL is set to a fixed level. Accordingly, optimal bandwidth usage of the control channel cannot be achieved through assigning a fixed MBL value in some cases, such as:

By having a fixed MBL value, a specific bandwidth will be scheduled for sending event driven messages like emergency messages. This result will leads to have wastage in the control channel bandwidth in times of not having notable number of event-driven messages to send or when a few numbers of

beacons are needed to be sent because of slow change of network topology in traffic jams on the highways.

We propose and implement an algorithm by which carrier sense (CS) threshold or Max-Beaconing Load (MBL) value can be assigned dynamically for fine-tuning the Distributed Fair transmits Power Adjustment for VANETs (D-FPAV) for control the congestion. In addition to optimal channel bandwidth usage [4], the proposed algorithm can be used in any situation considering traffic and non-traffic conditions. Our methodology for fine-tuning the D-FPAV algorithm is to employ dynamic MBL value instead of a fixed value. The implementation is based on the combination of transmitting message generation rate and power control. Dynamic MBL value makes the algorithm adjustable for traffic or non-traffic and event-driven or non-event-driven message conditions. Therefore, in this situation, emergency message have higher priority than beacon messages. The proposed methodology, more bandwidth will be reserved for transmitting emergency messages in the case of high traffic.

2. REVIEW WORK

In [1] M. S. Bouassida and M. Shawky have demonstrated a scheme to reduce the channel load and prevent the occurrence of congestion in the channels by adjusting the transmission parameters (transmission rate and transmission range) which has a significant impact on the condition of channels.

By increasing the transmission rate, the channels get overload and the congestion occurs. However, by decreasing the transmission rate, the VANET's applications faces lack of new information. The transmission range have to be increased to increase the number of vehicles receiving the messages in the communication range. Beside that, high transmission range will increase the rate of collisions. Therefore, tuning the transmission range and transmission rate seems to be an effective mean for controlling the condition of channels and the congestion in VANET [1].

The values of these parameters are compared with predefined thresholds (limits) to make the decision about congestion occurrence in the network. The predefined thresholds have a significant impact on the performance of networks for monitoring the communication channels and detecting the congestion. If the length of SCHs queue exceeds threshold value, it considered that the congestion occurs in that network then, the detected node controls the congestion by decreasing the transmission rate.

In [2] M. Torrent-Moreno, P. Santi, and H. Hartenstein demonstrated Distributed Fair Power Adjustments for Vehicular environments (D-FPAV) strategy that is a fully distributed and localized transmission power adjustment strategy. It provides an efficient transmission power for the emergency messages by decreasing the beaconing load where beaconing load is measured in terms of the number of nodes that

contain node u_i in their Carrier Sensing range. In fact, under the assumptions the beaconing frequency is fixed to the same value for all the nodes, and that beacon messages have the same size and the observed channel load is a function of the number of nodes in the surroundings. Note that the above definition of beaconing load can be easily extended for different beaconing frequencies in the network, and for beacon messages of different sizes on the channel below a predefined threshold while ensuring a high probability of beacon reception at close distances from the sender. Using D-FPAV, the event driven messages have higher priority compared to the beacon messages to transfer in the control channel. This strategy considers that the beaconing reception rates do not diminish at neighboring nodes. This strategy controls the congestion by adjusting the range of beacon messages based on vehicle density. In D-FPAV, each vehicle requires the overall information about the status of the neighboring vehicles located in the range. Based on this, the vehicles adjust the maximum transmission range for beacon messages such that the beaconing load does not exceed a fixed predefined threshold. Then, the adjusted transmission range is broadcasted to the neighboring vehicles located in their range.

D-FPAV makes use of transmit power control to achieve the following design goals [2]:

- i) Limit the maximum beaconing load (MBL) on the medium produced by periodic beacon exchange;
- ii) Maximize the minimum transmit power value, over all transmission power levels assigned to nodes forming the vehicular network, under constraint
- iii) The message prioritizing can be conducted to enhance safety and reliability of VANET. The safety messages should have the higher chance to access the control and service channels. Thus, a higher priority should be assigned to the safety messages. Prioritizing of the messages can be conducted based on different factors including messages content i.e. size of messages, type of messages, and so on, and the state of networks i.e. vehicles velocity, and utility of messages, and so on). In addition, the message scheduling can be carried out based on the defined priorities.

Assume a set of nodes $N = \{u_1, \dots, u_n\}$ is moving along a road modeled as a line2 of unit length, i.e., $R = [0, 1]$. Each of the network nodes periodically sends a beacon with a predefined beaconing frequency F , using a certain transmit power $p \in [P_{\min}, P_{\max}]$, where $P_{\min}(P_{\max})$ denotes the minimum (maximum) transmit power [2].

Power Assignment: Given a set of nodes $N = \{u_1, \dots, u_n\}$, a power assignment PA is a function that assigns to every network node u_i , with $i = 1, \dots, n$, a value $PA(i) \in (0, 1]$. The power used by node u_i to send the beacon is $PA(i) \cdot P_{\max}$ [2].

Carrier Sensing Range: Given a power assignment PA and any node $u_i \in N$, the

carrier sensing range of u_i under PA, denoted $CS(PA, i)$, is defined as intersection between the commonly known CS range of node u_i at power $PA(i) \cdot P_{max}$ and the deployment region R . The CS range of node u_i at maximum power is denoted $CS_{MAX}(i)$. Given a power assignment PA, the network load generated by the beaconing activity under PA is defined as follows:

Beaconing Load under PA: Given a set of nodes N and a power assignment PA for the nodes in N , the beaconing network load at node u_i under PA is defined as: $BL(PA, i) = |\{u_j \in N, j \neq i : u_i \in CS(PA, j)\}|$, where $CS(PA, j)$ is the carrier sensing range of node u_j under power assignment PA.

Beaconing Max-Min Tx power Problem (BMMTxP): Given a set of nodes $N = \{u_1, \dots, u_n\}$ in $R = [0, 1]$ and a value for the maximum beaconing load MBL, determine a power assignment PA such that the minimum of the transmit power used by nodes for beaconing is maximized, and the network load experienced at the nodes remains below the beaconing threshold MBL[2]. Formally,

$\max_{PA \in \mathcal{PA}} (\min_{i \in N} PA(i))$

subject to $BL(PA, i) \leq MBL \quad \forall i \in \{1, \dots, n\}$

where \mathcal{PA} is the set of all possible power assignments.

[3] Algorithm D-FPAV: (algorithm for node u_i)

INPUT: geographical positions of all nodes in $CS_{MAX}(i)$

OUTPUT: a power setting $PA(i)$ for node u_i , such that the resulting power assignment is an optimal solution to

BMMTxP

1. Based on the geographical positions of all nodes in $CS_{MAX}(i)$, use FPAV to compute the maximum common transmit power level P_i s.t. the MBL threshold is not violated at any node in $CS_{MAX}(i)$
2. a. Disseminate P_i to all nodes in $CS_{MAX}(i)$
b. Collect the power level values computed by nodes u_j such that $u_i \in CS_{MAX}(j)$ and store the received values in P_j
3. Assign the final power level: $PA(i) = \min\{P_i, \min_{u_j \in CS_{MAX}(j)} \{P_j\}\}$

In [3] Optimal bandwidth usage of the control channel cannot be achieved through assigning a fixed MBL value in some cases, such as:

Having a fixed MBL value, a specific bandwidth will be scheduled for sending event driven messages. This result in having wastage in the control channel bandwidth in times of not having notable number of event-driven messages to send or In case a few numbers of beacons are needed to be sent because of

slow change of network topology in traffic jams on the streets or highways.

Therefore, we propose and implement an algorithm by which CS threshold or Max-Beaconing-Load value can be assigned dynamically for fine-tuning the Distributed Fair transmits Power Adjustment for VANETs congestion control approach. In addition to optimal channel bandwidth usage, the proposed algorithm can be used in any situation considering traffic and non-traffic conditions. Our methodology for fine-tuning the D-FPAV algorithm is to employ dynamic MBL value instead of a fixed value. The implementation is based on the combination of transmitting power control and message generation rate. Using Dynamic MBL value makes the algorithm adjustable based on traffic or non-traffic and event-driven or non-event-driven message conditions. Therefore, in this situation, emergency messages should have higher priority than beacon messages. Through the proposed methodology, more bandwidth will be reserved for transmitting emergency messages in the case of high and low traffic.

3. PROPOSED SCHEME

Vehicular Ad hoc Network (VANET) is to provide life safety on the road as well as comfort to the automotive users. We assume that four different types of messages i.e., beacon messages, emergency messages, warning messages and query messages are used for communication in VANET. Each node maintains a control queue (CQ) to store the safe messages and a service queue (SQ) to store the unsafe messages. The control channel is used for the transmission of safety messages and service channel is used for the transmission of unsafe messages [6]. But in this case of high vehicle density the channel saturation may occur due to load caused by beacon message transmissions. These saturated channel conditions can lead to failure of reception of safety-critical information and, thus, will not contribute to the original goal of improving road traffic safety. The present work is a congestion control mechanism in vehicular ad hoc network by dynamically adjusting the beacon messages in order to ensure efficient bandwidth usage of control and service channel in VANET.

A. Type of message

Type I- Emergency Messages: - It is a vehicle to vehicle (V2V) communication where each message is generated by any vehicle (source node) which encounters an abnormal situation/condition or detects an imminent danger. It sends emergency message to all its neighboring nodes.

Message Format

TYPE	IDENTITY	CURRENT_LOCATION	TIME OUT	HOP_COUNT
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Fig1: Emergency Message

Type II- Warning Messages: - Such messages can be both vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication which are generated by a node (Source node) during traffic signal breakdown, jamming information etc. The Source node broadcasts this message to the nodes which are moving towards the jam location.

Message Format

TYPE	IDENTITY	CURRENT_LOCATION	TIME OUT	HOP_COUNT
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Fig2: Warning Message

Type-III- Beacon Messages: - Such messages are sent in triggered process (if some update is required) rather than periodically (i.e. after certain time period maybe after 30 seconds). It describes the situations (speed, positioning and direction) that help the other vehicles to understand about their surroundings. The load of the beacon messages i.e. MBL (Maximum Beaconing Load) can be decreased to bandwidth/3, when there is traffic or MBL value can be increased up to the maximum bandwidth of the channel when there is no traffic and no emergency messages around. Also, it can be set to $2 \times \text{bandwidth}/3$ when there is no traffic although there are event-driven messages around.

Message Format:-

TYPE	IDENTITY	CURRENT_LOCATION	SPEED
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Fig3: Beacon Message

Type-IV- Query Messages:-

Such messages can be both vehicle to vehicle(V2V) communication which are generated by a node (source node) to reach to a specific destination or query for nearest restaurant etc. and vehicle to infrastructure(V2I) communication which are generated by a vehicle to know the traffic condition of a particular road.

Message Format:-

TYPE	IDENTITY	MESSAGE	CURRENT_LOCATION	ROAD_ID	SPEED	TIME OUT
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Fig4: Beacon Message

B. Priority Assignment

A static priority is assigned to each message depending upon its type. The static priority of Type I, Type II, Type III and Type IV messages are assumed as Prio_I, Prio_II, Prio_III and Prio_IV, where $\text{Prio_I} > \text{Prio_II} > \text{Prio_III} > \text{Prio_IV}$.

C. Congestion Control Mechanism

In our proposed work, we consider dynamic MBL value instead of a fixed value which is based on the combination of message

generation rate and transmitting power control. Dynamic MBL value make our algorithm adjustable based on four different stages traffic or no traffic and event-driven or non-event-driven message conditions. Heavy traffic in the streets and highways can be detected from beacons information based on vehicles speed using the function detectTraffic(). If the average speed of the vehicles is less than 30km/h then there is heavy traffic in the highway otherwise the traffic is considered to be normal. However, the last state may not be generated due to the fact that the emergency message is issued in the case of abnormal conditions. Thus, the function adjustDynamicMBL() is used to dynamically adjust the MBL value in each of the above mentioned states. The MBL value can be decreased to bandwidth/3, when there is traffic or MBL value can be increased up to the maximum bandwidth of the channel when there is no traffic and no event-driven messages around. Also, it can be set to $2 \times \text{bandwidth}/3$ when there is no traffic although there are event driven messages around. Vehicles topology will change slowly due to heavy traffic in the streets. In this situation, using the proposed approach can decrease the number of beacons and consequently, the control channel overhead, can be reduced. Moreover, to say that traffic happens when there is an abnormal condition in a street. Therefore, in this situation, emergency messages should have higher priority than beacon messages. Through the proposed methodology, more bandwidth will be reserved for transmitting emergency messages in the case of traffic. As a result, the probability of receiving emergency messages will be raised as well as their reception range. The procedures for detection of traffic in the streets and assigning the MBL value dynamically are explained in details:

Procedure: detectTraffic (for any node)

1. Compute the neighbor vehicle average speed
2. If (80% of neighbor vehicles' average speed < 30km/h)

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

Else return false

Procedure: adjustDynamicMBL (for emergency messages)

If (detectTraffic == TRUE && emergency message == NULL)

/*Since, traffic occurs because of warning messages (PrioII), beacon messages (PrioIII) and

query messages (PrioIV)

And $\text{PrioII} > \text{Prio III}$ */

Return $\text{MBL} = 2 * \text{Bandwidth}/3$

If (detectTraffic == FALSE && emergency message == NULL)

Return $\text{MBL} = \text{Bandwidth}$

If (detectTraffic == TRUE && emergency message != NULL)

```
If (control channel == overloaded to transmit the emergency
message)
```

```
/* Since, traffic occurs because of Emergency messages
(PrioI), warning messages (PrioII), beacon messages (PrioIII)
and query messages (PrioIV)
```

```
And PrioI > PrioIII
```

```
Return MBL = Bandwidth/3
```

```
End If
```

```
Else
```

```
Return MBL = Bandwidth
```

```
End If
```

```
If (detectTraffic == FALSE && emergency message !=
NULL)
```

```
If (control channel == overloaded to transmit the emergency
message)
```

```
/* Since, traffic occurs because of Emergency messages
(PrioI), warning messages (PrioII), beacon messages (PrioIII)
and query messages (PrioIV)
```

```
And PrioI > PrioIII
```

```
Return MBL= 2*Bandwidth/3
```

```
End If
```

```
Else
```

```
Return MBL = Bandwidth
```

```
End If
```

```
Procedure: adjustDynamicMBL (for query messages)
```

```
If (detectTraffic == TRUE && query message == NULL)
```

```
/*Since, traffic occurs because of emergency messages (PrioI),
warning messages (PrioII)
```

```
Beacon messages (PrioIII)
```

```
And PrioI > Prio III */
```

```
Return MBL= Bandwidth/3
```

```
If (detectTraffic == FALSE && query message == NULL)
```

```
Return MBL= Bandwidth
```

```
If (detectTraffic == TRUE && query message != NULL)
```

```
/* Since, traffic occurs because of Emergency messages
(PrioI), warning messages (PrioII), beacon messages (PrioIII)
and query messages (PrioIV)
```

```
If (service channel == overloaded to transmit the query
message)
```

```
And PrioIII > PrioIV
```

```
Return MBL = Bandwidth/3
```

```
End If
```

```
Else
```

```
Return MBL = Bandwidth
```

```
End If
```

```
If (detectTraffic == FALSE && query message != NULL)
```

```
If (service channel == overloaded to transmit the query
message)
```

```
And PrioIII > PrioIV
```

```
Return MBL = 2*Bandwidth/3
```

```
End If
```

```
Else
```

```
Return MBL = Bandwidth
```

```
End If
```

```
Procedure: adjustDynamicMBL (for warning messages)
```

```
If (detectTraffic == TRUE && warning message == NULL)
```

```
/*Since, traffic occurs because of emergency messages ( PrioI),
beacon messages (PrioIII) and
```

```
query messages (PrioIV)
```

```
And PrioI > Prio III */
```

```
Return MBL= Bandwidth/3
```

```
If (detectTraffic == FALSE && warning message == NULL)
```

```
Return MBL= Bandwidth
```

```
If (detectTraffic == TRUE && warning message != NULL)
```

```
/* Since, traffic occurs because of Emergency messages
(PrioI), warning messages (PrioII), beacon messages (PrioIII)
and query messages (PrioIV)
```

```
If (service channel == overloaded to transmit the warning
message)
```

```
And PrioII > PrioIII
```

```
Return MBL= Bandwidth/3
```

```
End If
```

```
Else
```

```
Return MBL = Bandwidth
```

```
End If
```

```
If (detectTraffic == FALSE && warning message != NULL)
```

If (service channel == overloaded to transmit the warning message)

And PrioII > PrioIII

Return $MBL = 2 * \text{Bandwidth} / 3$

End If

Else

Return $MBL = \text{Bandwidth}$

End If

4. CONCLUSION

In our proposed work, we have discussed about congestion control which is one of the major challenges in VANETs which occur due to limited bandwidth in the communication channels. DFPAV [2] is improved by dynamically adjusting the MBL value in four different stages traffic or non-traffic and event-driven or non-event-driven message condition. This scheme can decrease the number of beacons and consequently, the control channel overhead can be reduced. Moreover, needless to say that traffic happens when there is an abnormal condition in a street. Therefore, in this situation, event-driven messages should have higher priority than beacon messages. Through the proposed methodology, more bandwidth will be reserved for transmitting event-driven messages in the case of traffic.

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