Congestion Control Scheme for Vehicular Ad-Hoc Network (VANET)

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Abstract: *Vehicular ad hoc network (VANET) is one of the most modern and promising technologies for revolutionizing the transportation system where vehicles can communicate via a wireless medium. The IEEE 802.11p includes communication between vehicles (V2V) and between vehicle and roadside infrastructure (V2I). VANET provide the communication framework for dissemination of safety critical message such as beacons and emergency messages. Technological involvement increasing number of wireless devices which also creates more congestion in the wireless environment and greatly effect on the throughput, increases high-error rate, long-latency and data loss in congested environment which may leads to major vehicle accidents. So, the scheme which controls congestion is necessary to regulate the traffic level at an acceptable level. The proposed scheme includes study existing 802.11p standard and develop an algorithm on MAC to modify parameters like transmit power, contention window and packet interval to reduce the congestion due to heavy broadcast traffic in the network for VANET.*

Keywords: VANET, Congestion, MAC

1. Introduction

Vehicular Ad-hoc network (VANET) is similar to Mobile Ad-hoc network (MANET) but in VANET vehicle act as node instead of mobile act as a node in MANET.VANETs are key component of intelligent transportation system. This approach is more effective as each vehicle in the communication range try to solve their problem individually. VANET provide two types of communication. One is vehicle to vehicle communication and other is vehicle to infrastructure communication. The message forwarding and propagation should be done in small amount of time. Therefore, reliability and low delay are extremely important factors for VANET applications to propagate and disseminate the message to the region of interest. Fig.1 shows the communication between the vehicles and roadside unit. Each vehicle has the on board unit (OBU) which is resides in the vehicle. Which help to share the information with other OBU or Road side unit(RSU).It has network device for wireless communication based on IEEE 802.11p radio technology. Here RSU also has network device to add the communication capability for short range wireless communication using IEEE 802.11p. VAET require IEEE 802.11p specification which include data exchange between the high speed vehicles. IEEE 802.11p is an approved minor change to IEEE 802.11 to add wireless access in vehicular environment (WAVE).All the short range radio technology like Wi-Fi, Bluetooth, Zigbee, visible light communication for communication purpose.
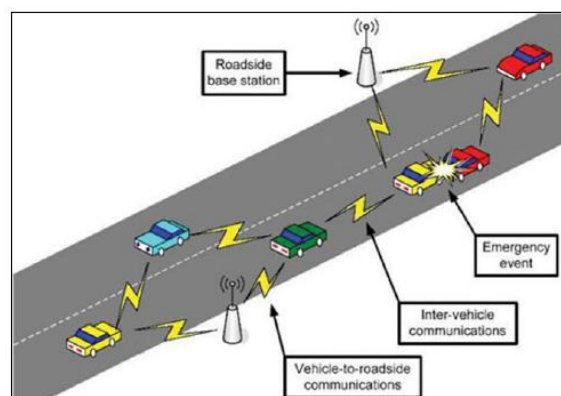

Figure 1: Communication between vehicles and roadside unit[1]

As VANET use short range radio technology for communication purpose, the Federal communication commission has allocated 75 MHz of dedicated short range communication (DSRC) at frequency range of 5.9 GHz to be used for vehicle to vehicle and vehicle to infrastructure communication. This spectrum is divided into seven channels. One control channel and six service channel. Control channels are used to transmit the safety related message like beacons and event driven message. Beacon messages are periodically send by the every vehicle which includes their speed, location direction of travel to their neighboring vehicle. So using this beacon message vehicle can count number of surrounding vehicles. Event driven message are generated when the vehicle detect any abnormal situation. Six service channel are used to transmit non safety message like sharing file, gaming, web surfing, file download, finding nearest eating joits, theatre, petrol pump, nearest parking availability[3][8].

1.2 Characteristics of VANET

Highly Dynamic topology : The speed of the vehicles in the different traffic condition such as during rush hours, traffic light, traffic jam, accident, late night and school

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area are different which result in dynamic topology of the vehicular network[2].The topology of the network can be change by driver behavior due to his/her reaction to the messages[4].

Dynamic Node Density: Due to road architecture, highways and city environment node density is frequently vary. As to network density is depend on node density, the network density is also variable for example during traffic jam condition, network can be called highly dense network while in suburban traffic it is characterized as sparse network[2][4].

Frequent Network Disconnection: Due to the dynamic nature of vehicular topology there is rapidly change in the link connectivity of VANETs which result in frequently network disconnection. For example during the late night and in rural area vehicle move with high speed so communication link between vehicle remain active for very short duration of time[2].

Hard delay constraints: The main application of the VANET is to provide safety so message related to safety is propagate on timely manner to avoid further congestion and collision[2].

1.3 Application of VANET

Safety: These applications basically focus on the reduction of the road accident, saving human life avoids collision. safety application include lane changing warning, sudden halts warning, obstacle discovery, warning on departing the highway, warning on entering intersection related messages[2].

Direction and Route Optimization: For reaching our destination there are usually many path available so by collecting the relevant information system can find best related path in terms of travel time, fuel and toll.

Policing and enforcement: which include speed limit warning and restricted entries related messages.

Travel Related Information: when unfamiliar driver enters in the new city than he/she don't know about the available services like gas location, car services location, petrol pump, business related location etc. using this approach driver can find this information by communicating with other vehicles and road side unit.

General Information Services: As VANETs are integrated to internet, general application of internet like sharing the files, file download, gaming, web surfing, email are also available.

As per 802.11p amendment of IEEE 802.11 for vehicular access in wireless environment, for all V2V (Vehicle to vehicle) communication all vehicles must use the same channel to transmit the safety data. All vehicles transmit broadcast safety message at some regular interval and / or at some critical time. As the number of vehicles increase in the range it increases the collision of wireless packets. As the messages are broadcast, there is no mechanism to detect collision for broadcast frame. So it needs some changes at MAC layer to reduce congestion / collisions.

The remainder of this paper is organized as follows. In section 2, related work is presented. In section 3, proposed solution is briefly presented. Section 4 provides the simulation results. Section 5 gives conclusions.

2. Related Work

In [5], author proposed joint adaptation of transmit rate and power to reduce channel congestion in vehicular Ad-hoc network. The rate and power adaptation directly effect on number of messages exchanged & number of vehicles in the awareness region respectively. By setting the collision rate value i.e. acceptable collision rate value (5% here) proposed algorithm adapts TR/TP value according to observed collision rate. Initially TR/TP value is selected between the interval $(TR/TP)_{minimum}$ and $(TR/TP)_{maximum}$ values .If collision rate is higher than acceptable collision rate then it picks a TR/TP value in the interval between $TR/TP_{minimum}$ and current TR/TP value & if the collision rate is lower than acceptable collision rate then it picks a TR/TP value in the interval between current TR/TP & $TR/TP_{minimum}$ value. When communication overhead increases, collision rate also increases. To reduce collision rate first rate adaptation is applied until minimum required rate is reached and if the collision rate is still high then power adaptation is applied.

In [6], author proposed probability based MAC channel congestion control mechanism (PCC) to decrease channel congestion in vehicular environment. In this mechanism two functions are used called contestant estimation function and expected offset calculation function. In contestant estimation function each vehicle can count number of surrounding vehicle based on listening hello message in the listening interval. While in expected offset calculation function vehicle calculate the length of the offset slot based on surrounding vehicle. The main advantage of PCC mechanism is that each vehicle in the network vary the contention window size according to the number of neighboring vehicle. Here the CW value increases when number of vehicle increases.

In [7], author proposed joint adaptation of transmission power an contention window size to reduce channel congestion in vehicular environment. The speed of the vehicle is different in the different traffic condition like during traffic jam, traffic light, accident which results in dynamic topology of vehicular network. Also during late night and rural area the vehicle speed is very low so the connection between vehicles remains active for very short duration of time. To make this connection for long time one solution is there increase transmission power but it create high network interference and overhead. To overcome this problem dynamic adaptation of transmission power which means increase transmission power when local vehicle density is low and decrease transmission power when local vehicle density is high? Due to the prioritization of messages, messages related to accident have higher priority compare to other messages so they have lower contention window size which result in high transmission opportunity compare to other. According to current collision rate, increase or decrease respective contention window size.

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In [8], author proposed adaptive congestion control transmission of safety messages to deliver accident related message on timely manner without any delay. Here first create the vehicular network after that partition that network into equal width of segment. The vehicle which is near to the center of the segment will be selected as the local coordinator. This local coordinator assigns the time slot to each vehicle in that segment for beacons transmission. In the case of emergency message, time slot reservation carried out dynamically and time slot will be reserved for emergency message. So by using this mechanism emergency messages can be transmitted on timely manner without expense of beacons.

In [9], author proposed adaptive and reliable medium access control mechanism by combining carrier sense multiple access with time division multiple access to avoid collision effectively and use wireless resources efficiently. Here they introduce variable duration concept called "Chip" which have transmission period (TS) and reservation period. Transmission period is basically series of TDMA slots which is used by the nodes for their transmission while reservation period used by just newly incoming node to reserve a slot for transmission. When the local vehicle density is low then the duration of chip is short, for this case rest of the control channel duration can be used by the service channel to improve the throughput of the service channel. When the local vehicle density is high then the duration of the transmission period of control channel duration is high to make sure that every vehicle can transmit their safety packet successfully. In this case the duration of the control channel may be longer than service channel.

3. Proposed Solution

In the proposed technique, we will take the advantage of the MAC layer parameters which provides better performance and control in congestion of the broadcast domain in wireless network. First we understood the 802.11p standard and the congestion in the environment when multiple vehicles communicate with each other for warning and safety messages. All the nodes / vehicles transmit safety messages at regular configured interval at the configured data rate and the transmit power. Each node / vehicle sends and extra information like own mac address, transmit data rate, transmit power, own contention window (CW) value, node number appended in the data payload. For V2V communication, each node broadcast this information in the message so all the node receiving the frame would parse the node information and maintain the node table which includes information of all the nodes in its range. The MAC layer parameters slot-time, transmit power, broadcast data rate, CWmin value, packet interval etc. will be modified from its default values to enhance the broadcast congestion in the network.

4. Proposed Algorithm

This algorithm will be developed in Network Simulator–3 tool.

- Developed the program in this simulator which will contain wireless stations works in ad-hoc mode in 802.11p for V2V. Create X wireless stations in ad-hoc mode. This number of wireless stations for the test can be increased to any number.
- Place all the X wireless nodes with distance of 100 meters each.
- Generate safety messages/packets (broadcast) from the wireless devices. (1000 packets from each nodes with 500bytes of packet size).
- Monitor the received traffic (safety messages) generated by the wireless nodes on any single observer node in the network. Calculate the message drop rate due to congestion in the network as result-1.
- Every device would send the information regarding its own MAC parameters (i.e. slot time, tx power, broadcast data rate, CWmin value, packet interval etc.) of the node in safety message as a part of data payload. These information is used to making some decision making task to control congestion in the medium.
- Monitor the safety message generated by each node on every single node and configure itself with proper configurations based on the other nodes in the surroundings.
- Modify the MAC parameters on the each wireless node properly based on the other nodes around it (i.e. slot time, transmit power, broadcast data rate, CWmin value, packet interval etc.) in the wave/Wi-Fi MAC layer of the NS-3 framework.
- Monitor the traffic again with the single observer node and calculate the message drop rate as result-2.

The Congestion in result-2 would be observed lower from the result-1. This difference is the control over congestion by the proposed algorithm.

Dynamic Algorithm – 1 (TX Power)

If the neighbor node count reaches to its threshold value then the node would change its Transmit power (Tx)to lower value than the current one. (E.g. if the current transmit power is 23 dbm then it would decrease it to 20dbm). This will reduce the range and this node will not interfere the node which is at far distance. This way, the nodes which are far away from each other's range can transmit simultaneously.

Gather the information and count of the neighboring node
If (neighbor node count > threshold) {
 Decrease the Transmit power;
}
else
 {
 Keep the Transmit power same;

5. Simulation Result

For simulation of the congestion control techniques, we have used Network Simulator as a programming tool, NS-3 version. We have implemented the scripts of network simulator to simulate our experimental scenario of wireless

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nodes and its visualizer for graphical representation & I have captured the RF congestion in the network.

Table 1: Simulation Parameters for Experimental Setup

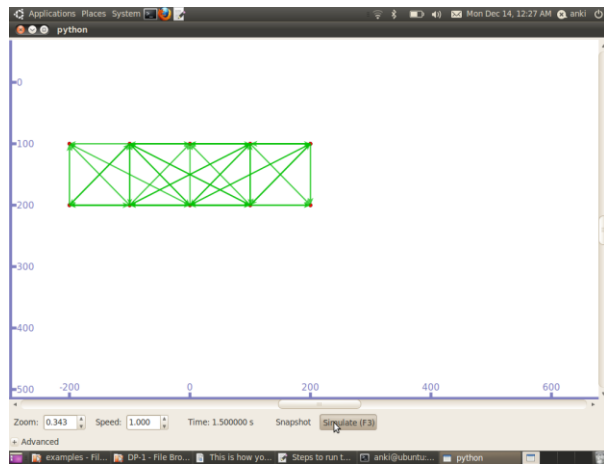| Parameter	Value/Description
Number of Nodes in the Network	10 Nodes (can be varied)
Packet Size	500 bytes
Number of packets	100 packets
Message Interval	100 ms
Broadcast data rate	6 Mbps
Transmit Power	varied based on surrounding nodes

Figure 2: 10 Nodes transmitting with default scheme

As shown in figure 2, if the number of node is less(10) then node cannot interfere with other node and cannot create the congestion even if higher transmit power(default scheme). But if the number of node increases(40) then with higher transmit power more congestion in wireless environment as shown in figure 3.figure 4 shows the result of proposed scheme, in which for more number of node, the transmit power is less which reduce the congestion. Similarly we can adapt the contention window and packet interval value according to number of nodes.
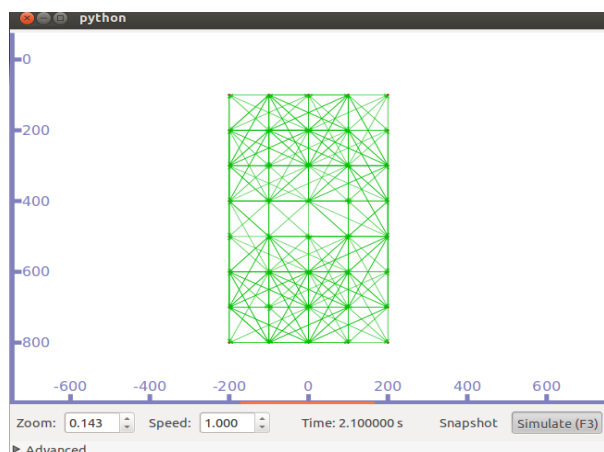

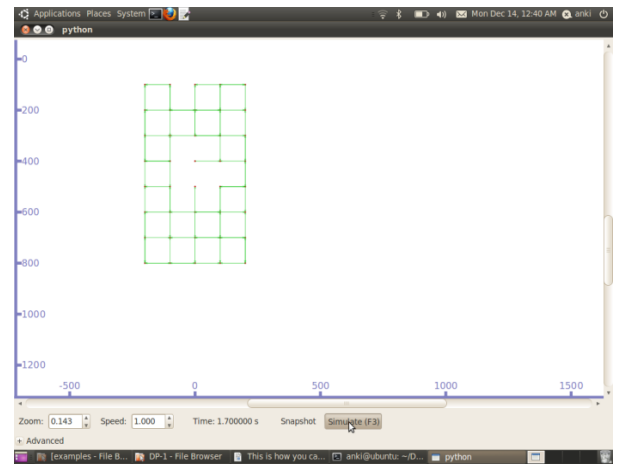**Figure 3:** 40 Nodes transmitting with default scheme

Figure 4: 40 Nodes transmitting with proposed scheme

6. Conclusion

By dynamically adaptation of transmission parameter like transmit power according to number of nodes we can reduce the congestion in vehicular Ad-hoc network. We can also adapt the parameter like packet interval, contention window according to vehicle density in future.

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