Impact of Congestion on Applications of Vehicular Ad-Hoc Network

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Abstract: Technological innovations have improved the quality of life; thousands of kilometers can be traveled in hours or less. Vehicular Ad Hoc Network (VANET) has become a promising topic in research community due to its various applications like safety, infotainment, and traffic management application. VANET supports Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication. With an increase in the number of vehicles on the road, the number of vehicle accidents is also increasing in equivalent pace. Therefore, safety is the essence of daily life; to reduce this adverse effect vehicle to vehicle communication is predominantly required. For safety applications, vehicle broadcast two types of messages that are beacons and emergency messages. Beacons include vehicle status like position, velocity, speed, etc. are disseminated periodically. Vehicles for safety application broadcast self-information messages, which sometimes results in congestion due to increasing vehicle density. To avoid congestion, our attention is towards designing a MAC protocol that utilizes the communication medium efficiently; reliable and undelayed message reception are taken into consideration. The most challenging task is to deliver emergency messages before the deadline. VANET other applications also had made Internet services available during traveling and had given a smooth shape to traffic. The characteristics, applications, review of the challenges of VANET such as congestion is discussed. we present the existing congestion control techniques in decentralized vehicular environments also known as Decentralized Congestion Control (DCC), and a comparative analysis is performed of the schemes.

Keywords: VANET, DCC, Congestion Control

1 Introduction

Road traffic safety has been a worldwide issue due to an increase in death rate caused by road accidents. A report from the World Health Organization (WHO) states that approximate one and half a million people died due to road accidents in 2013 [1]. Road fatalities may be reduced by providing information to vehicles, regarding traffic status, and danger ahead, etc. through safety messages. VANET is safe, secure and efficient transportation existing and future applications. Safety messages envisaged to support life-critical safety message dissemination such as intersection collision, emergency electronic brake lights, safety warning, lane change assistant, etc. VANET has mainly two type communication mode, one is vehicle to vehicle (V2V), and another is the vehicle-to-infrastructure (V2I). Components related to the vehicle are On-Board Units (OBU), which are mounted on the engine of the vehicle and helps in establishing communication between OBU/RSU or OBU/OBU, Roadside Unit (RSU) which is also known as infrastructure. RSU is the device mounted on the roads either on street light, traffic light, etc. and Authentication unit (AU) which helps in executing an application for communication.

For safety messages, the foremost requirements are strict delay sensitive and reliability as they are hard time-bound. In 1999, US Federal Communication Commission allocated 75 MHz of spectrum in 5.9 GHz band to be used by Intelligent Transportation System. IEEE802.11p [2] is the dedicated standard specified by IEEE Wireless Access in Vehicular Environment (WAVE) [3] used for Medium Access Layer (MAC) and physical layer of VANET protocol stack. For V2V and V2I communication, Dedicated Short Range Communication (DSRC) radio are mounted on vehicles . DSRC is

MAC protocols play a major role in scheduling safety messages transmissions, aim to provide a fair and harmonized channel access. At MAC layer, vehicle disseminates two types of messages that are periodic (beacons) and event-driven messages (emergency). For safe communication, vehicle disseminates two type of messages that are Cooperative Awareness messages (CAMs) and Decentralized environmental messages (DENMs) also known as event-driven messages. DeNMs are the safety messages generated by the vehicle in case of emergency situations also known as event-driven messages. CAMs are the messages disseminated by the vehicles to give its basic information like position, velocity, speed, etc. also known as beacons. As the number of vehicle increases, it increases the number of beacons in the communication channel that lead to congestion. Therefore, the question arises how much is the congestion impactful?

As the density of vehicle increases, the number of beacon transmission in the communication channel also increases. However, the channel becomes exhausted, results either lost or delay of emergency messages. Therefore, congestion has a great impact on the effectiveness of the safety messages. Congestion increases latency and decreases reliability for the transmission of highly critical emergency messages. It is important to low the beaconing load on the communication channel for better reception of emergency messages. Therefore, safety application important metrics are reliability and dependability [4]. Dependability means the message disseminated by the vehicle should reach the destination before the deadline. However, the brief introduction of VANET protocol stack is provided in Fig.1 where the DSRC control channel (CCH) is used for safety application communication. provides. The protocol stack is being divided into four major layers.

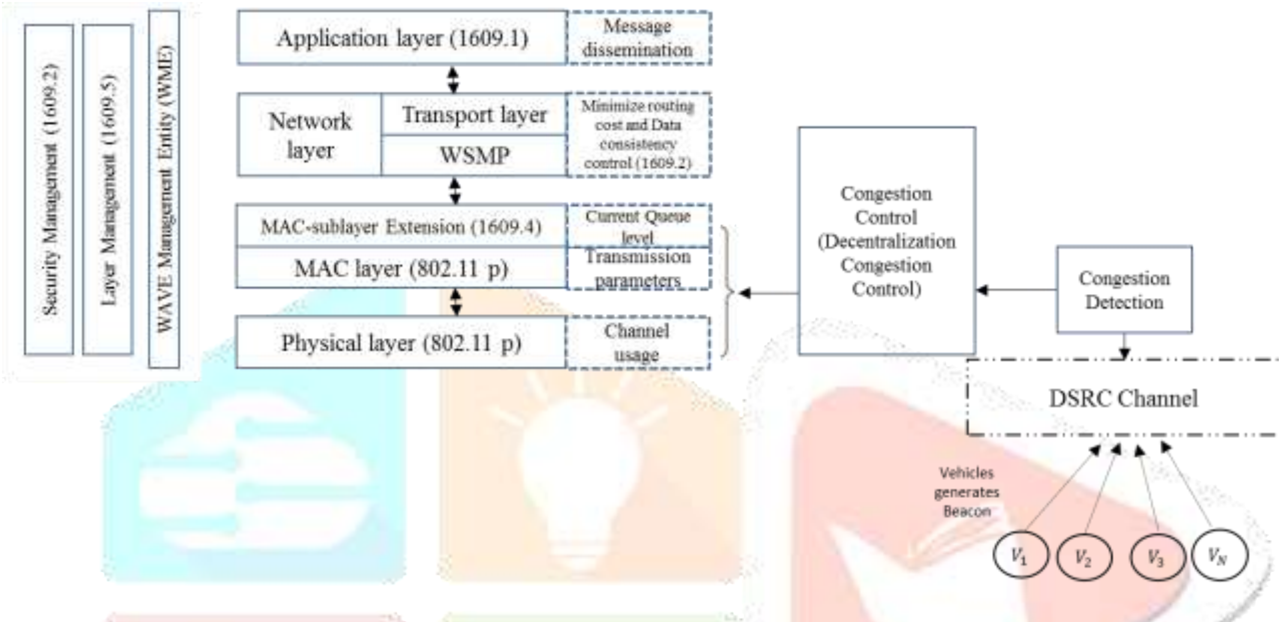

Fig 1.1: VANET protocol stack

Protocol stack has following components as DCC-mgmt located in management layer, DCC-net in network and transport layer and DCC-access located in the access layer. The access layer is a combination of physical and MAC layer. To control the congestion due to the beacon in the communication channel, Decentralization Congestion Control schemes [5] is incorporated in the lower layer of the protocol stack. This is a cross-layer framework by the European countries also named as Cooperative Intelligent Transportation System(C-ITS) [6]. DCC schemes measure the channel load and adjust the vehicle transmit parameters to control the congestion discussed in detail in section 2.

1.1 *Characteristics of VANET*

VANET is a special class of MANET due to its following characteristics.

- High mobility – Nodes (vehicle) changes their position at high speed according to the scenarios. For urban scenario the speed of the vehicle is very low, i.e., between 30 km/h and 50 km/h and rural area the speed is moderate, i.e., between 50 km/h and 80 km/h. But for highway scenario vehicle has very high speed, i.e., between 90 km/h and 150 Km/h.
- No Energy constraint – VANET is unlike MANET, as latter one has battery issues. i.e., its life depend upon mobile device battery. VANET has ample of storage, processing, and no energy constraint.

  Quality of Service Requirement – This characteristic is according different application. QoS requirement for different VANET application like for safety high reliability and low latency should be given higher priority than other messages. Traffic management application QoS requirement is a packet loss ratio and reliability.
- No central Coordinator – In VANET communication is decentralized manner. Therefore, there is no need for a coordinator.

1.2 VANET application

To make our transportation system safe, secure and efficient, VANET is used in many of the existing and future applications like life critical warning, e-Toll, Internet service during traveling, group communication and roadside service finder [7]. Therefore, VANET application has been categorized: Safety applications, Traffic management applications and User application [8].

Traffic management application helps in the best route making decision, helps in avoiding congestion on the roads and VANET applications are an e-Toll plaza, parking availability notification, etc. Infotainment application is also essential for information and entertainment. Using this application user can access the internet while traveling in a car. Traffic management applications require low latency and minimum transmission delay, while user applications need high bandwidth utilization.

1.2.1 Safety application

Safety application is the most prominent area and has important aspects of human life. Reliable and time-bound are the two criteria that have to be satisfied regarding safety messages. Safety messages have been classified into two categories that are-

1.2.1.1 Event-driven safety message

Event-driven messages further have been categorized into two classes [9] as shown in Figure 1.2, i.e. first, includes situations that are most critical such as life-critical safety, intersection collision avoidance, and emergency brake avoidance. This class of message is very important and has to reach vehicle before the deadline. Second, includes long-range emergency notification messages example are safety warning, transit vehicle signal, and cooperative warning. Event-driven messages [10] may occur whenever some event occur such as traveler help, public serving, road condition alert, collision awareness and public services

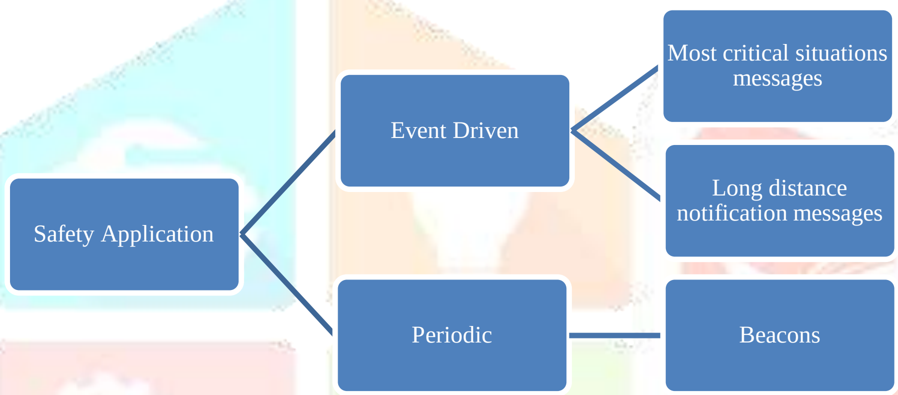

Fig 1.2: Classification of safety applapplications

- ➢ Traveler Help
  - Post-crash notification – Periodically vehicle share information with the infrastructure to avoid a collision and generate a notification.
  - Prosaic crossing- Roadside unit broadcast message to the vehicle to reduce his speed for nearby pedestrian crossing.
  - Parking spot alert- This alert helps in places like malls, hospitals, etc. to quickly park vehicle.
- ➢ Public serving
  - Stolen vehicle traversing- This helps vehicle owner or police to search for their stolen vehicle. Since the basic requirement is to install a tracking device.
  - Emergency site reachable warning- In this either the RSU or the vehicle disseminate warning to the emergency vehicle to reach the site.
  - Emergency brake notification- Notification generated when a vehicle applied emergency brakes.
- ➢ Driving alarming signal
  - Lane change and merging alert notification- This reduces the chances of an accident that mostly take place during either overtake or blind spot.
  - Emergency brake notification- If there is any road accident ahead, then infrastructure or vehicle broadcast notification to have an emergency brake on the vehicle.
- ➢ Collision awareness
  - Wrong way alert - This is alarming to the vehicle driver if he took a wrong way to his destination.

- Intersection collision alert - In this use case, the risk of lateral collisions for vehicles that are approaching road intersections.
- Traffic signal violation alert - This broadcast message to all the vehicles approaching towards traffic signal providing information about the signal. This alert helps the vehicle to slow down its speeds.

1.2.1.2 Periodic safety message

Each vehicle disseminates periodic safety message also known as Cooperative Awareness messages (CAM) or beacon. It includes basic information about the vehicle such as vehicle speed, direction, position, etc. CAM is also very important for safety applications in order to know the vehicle position.

1.2.2 Traffic management application

The traffic management application managed traffic on the roads and used for planning trips. It calculates the best route for solving road congestion problem. E-toll plaza, intelligent traffic signals, park availability notification, etc. are some of the categories of traffic management application.

In E-toll plaza application, the drivers do not have to stop their vehicles for paying the toll. Congestion at the intersection is tackle by an automatic traffic signal. Traffic lights get adjusted according to the density of vehicle so that it will not lead to traffic jams. However, traffic flow at the intersection is handled by reflecting the periodical status on e-board.

The Park availability application assists in recognizing the availability of the parking lot. The only limitation for these applications is to frequently maintain and update the relevant information. All above applications require the vehicle to infrastructure communication. The Congestion Road Notification is a traffic management application for VANET. By this congestion on the road can be notified which is helpful in route guidance. CRN application also assists drivers to plan trips by avoiding road traffic and reach the destination in minimum time.

1.2.3 User Application

Nowadays, entertainment is needful. User application helps in providing the information and use of internet access during traveling [11]. The peer-to-peer application also provides different facilities for entertainment like playing the game, chatting, etc. that provide the advantage of less deprivation of work while traveling. Therefore, people can access every corner of the world.

2 Congestion Control

Congestion control is a key functionality in communication; it ensures high reliability and low delay in delivery of emergency messages. At MAC layer, congestion is controlled either by two methods shown in Fig.1.2 first, by using Time Division Multiple Acess (TDMA) for communication channel replacing the existing Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) adopted by IEEE 802.11p standard. Secondly, by adopting crosslayer congestion control schemes (i.e. DCC) .

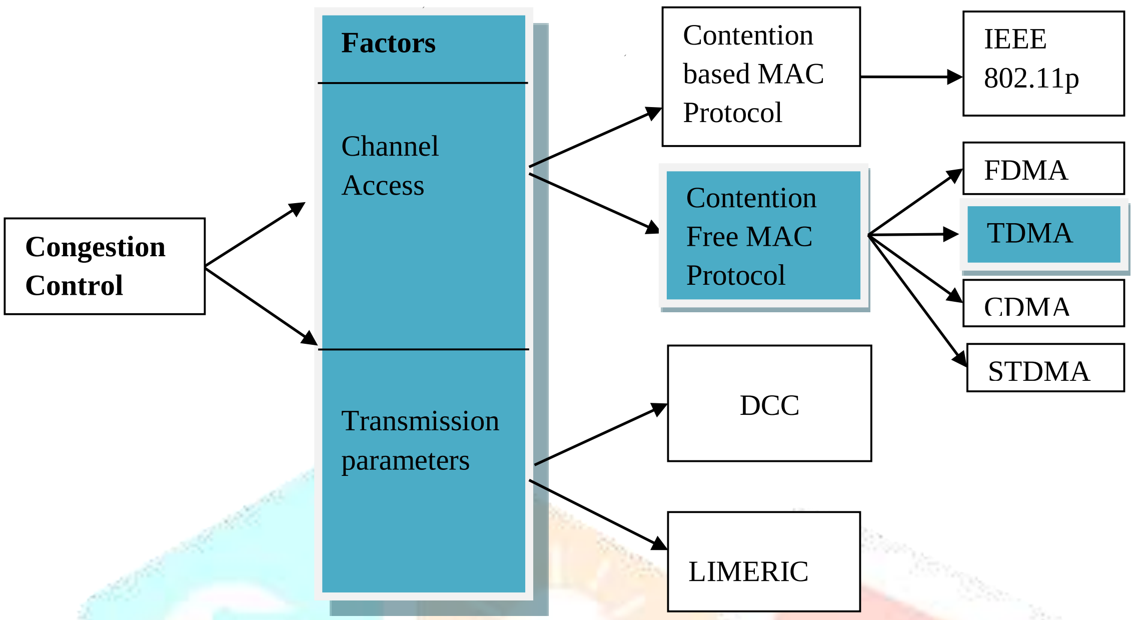

Fig 2.1: Classification of Congestion

DCC is a cross-layer scheme that varies the parameter setting of the physical layer based on a reference measured in the MAC layer. Either by minimizing the transmit power, packet generation rate, or varying some of the threshold values the channel load of the communication channel can be reduced. Although, the DCC scheme is being amended at the combination of physical and MAC layer (cross-layer approach).

We have classified DCC schemes into two methods such as :-

1. Reactive
2. Adaptive

Conventional DCC is also known as reactive congestion control that simulates DCC regarding three states but it does not produce sufficient result therefore extended to six states. Later on, adaptive DCC was introduced that uses binary control [12]. DCC reduces congestion on the communication channel by measuring the channel load by adjusting transmit parameters. Channel load is measured by a number of vehicles transmitting messages.

The DCC mechanisms are as follows:-

- TDRC – This transmits data rate control that controls the rate of the packet a vehicle transmit packets.
- TPC – This transmits power control that means the average power per packet.
- PI – The time interval taken by vehicle to transmit packet also known as TRC (transmit rate control).
- CCA – This clear channel assessment which acts as an indicator whether the communication channel is free or busy for vehicle access.
- Transmit Access Control- introduces a transmit queue concept to handle packet priority.

DCC consists of three states, i.e. Relaxed, Active and Restrictive [4]. Each state has its own DCC transmit parameter setting. In relaxed state the number of vehicles is very less, active means moderate and then restrictive is a congested scenario where mitigating congestion is troublesome.

Mostly, the researchers have worked on transmit power [13], [14], [15] then some authors find transmit rate to be more efficient [16] ,[12] ,[17], and then many researchers work on both the parameters together. In 2010, Huang et al. [18] proposed adaptive DCC communication model where transmission power is adjusted on-demand for safety application. In 2012, Sundar Subramanian et al. [19] proposed synchronous TDM is overlayed on the top of the MAC layer that to bypass the backoff procedure in IEEE 802.11p. Sebastian Kuhlmorgen et al. [20] proposed a DCC gatekeeper new enhancement in DCC model shown in Fig. 4 which controls the message rate according to the active channel load. It is incorporated in C-ITS stack on the top of Access layer. DCC gatekeeper acts as a traffic shaper and regulates data packets with the help of control algorithm. It also separates the data packet according to the priority in separate queues. In ESTI- EN 302-637-2 and -3 has standardized mostly two type of messages-

1. Cooperative Awareness messages (CAM)
2. Decentralized Notification messages (DENM)

CAM is an event-driven message, which has high priority and DENM is the periodic message. Above model can be translated into multi-queue, but now it has four queues with limited size.

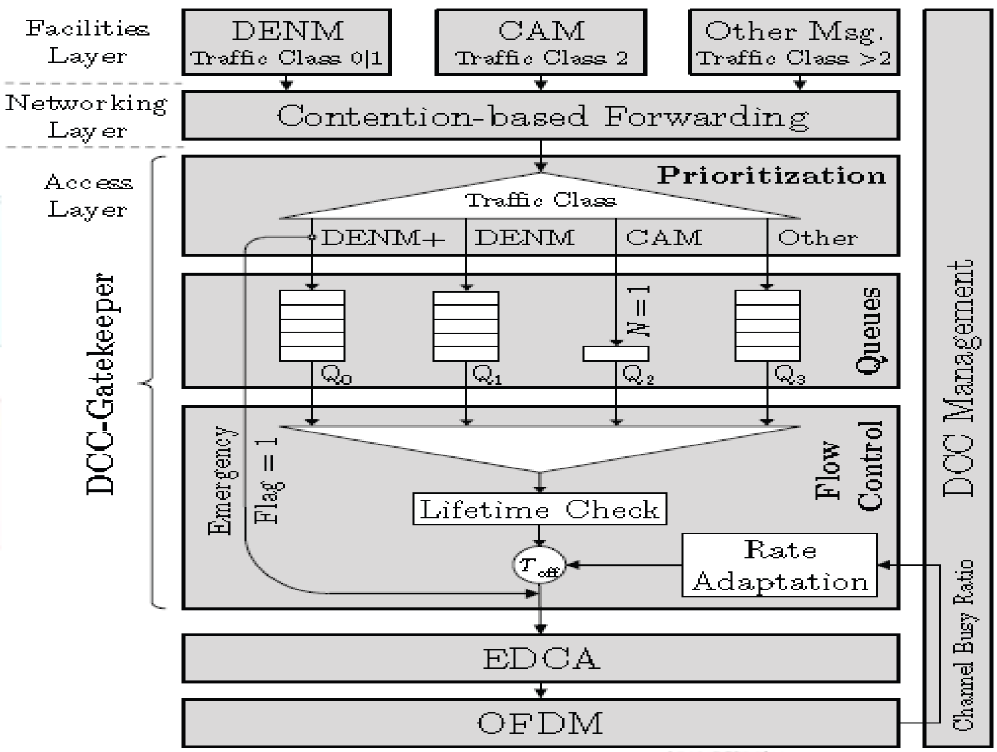

Fig 2.2 : DCC- Gatekeeper with priority Queue [20]

Priority Queue - In above Gatekeeper-stack there are three priority queue for different messages CAM messages, second for DENM messages and third for other messages. Then the messages are queued according to ascending priority, but DENM message which is highly critical are queued to Q_o which bypass the other queues. Then the messages are handed over to the EDCA for traffic categories (Enhanced Distributed channel access).
DCC Queue - There are four queues named as Q_0 , Q_1 , Q_2 and Q_3 with descending priority. The queue has limited size and works on FIFO property.
DCC flow control - This helps in scheduling packets from queues on the basis of priority. Therefore high priority queue becomes empty first. If packet queuing time gets exceeded, then the packet is discarded. The flow control mechanism is different from EDCA as it handles single packet at a time. Therefore, it shows that DCC is a more effective technique used for controlling congestion in the communication channel. It makes safety applications more powerful and useful in saving thousands of lives. An comparative analysis has been presented i n the Table 2.1 compares according to their features.

Table 2.1 : Classification of DCC schemes.

Title	Published Year	Transmit Parameters	Scenario	Applications	Network Simulator	Propagation Model
Opportunistic technique for efficient wireless vehicular communications	2007	Transmit Power	Intersection Urban	Safety application	NS-2	WINNER
Analysis and Design of Effective and Low-Overhead Transmission Power Control for VANETs	2008	Transmit Power	Highway	Safety application	NS-2.31	Nakagami-m
Rate adaptation based congestion control for Vehicle Safety Communications	2011	Transmit Power	Static highway crossing and Dynamic highway scenario	Safety application	NS-2	Rayleigh fading, Nakagami
Efficient message dissemination via adaptive(ATB)	2011	Transmission rate	Highway	Multimedia	OMNeT++	N/A
CCA threshold adaptation depending on how long a packet has been waiting for medium access	2011	Carrier sensing threshold	Highway	Safety application	JiST/ SWANS	Rayleigh Fading
AIMD	2011	Transmission rate	Urban intersection	Safety application	Author simulator	N/A
Congestion Control for Vehicular Safety: Synchronous and Asynchronous MAC Algorithms	2012	Transmit Power	Highway	Safety application	NS-2	N/A
SuRPA	2014	Transmit rate and transmit power	Highway	Safety application	NS-3	Corner propagation loss model
Extension DCC	2016	Transmit Rate	Highway	Safety application	NS-3	Nakagami

4. *Conclusion*

Safety is our day to day need; the paper shows the importance of DCC for V2V communication for safety applications. DCC helps in reducing congestion and has improved in terms of reliability, latency rate, minimum packet loss ratio and maximum throughput. Transmit parameters at physical layer are controlled according to the vehicle density estimation. Vehicle density estimation schemes but still need to propose accurate estimation of vehicle density.

DCC Queue has limited size; therefore the synchronization between packet rate and service rate does not match. DCC flow control firstly processes higher priority queue that sometimes results in lower priority queue packet suffer from starvation. The above limitation can be considered as a subject for the future scope and to build an efficient MAC protocol for safety applications.

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