International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

A Novel Mac Based Congestion Control System for VANET with Adaptive Routing

Mahanthgouda[1], Sridhara. K[2]

[1]M. Tech, Department of Electronics and Communication Engineering
Poojya Doddappa Appa College of Engineering, Gulbarga, Karnataka, India

[2]Associate Professor, Department of Electronics and Communication Engineering
Poojya Dooddappa Appa College of Engineering, Gulbarga, Karnataka, India

Abstract: ***VANET is a inter vehicular and vehicle-road side unit wireless communication network that was evolved specifically for exchanging GPS data among vehicles along with exchanging important alert messages like congestion notification. VANET differs from other wireless networks like MANET and WSN in data transmission and routing because the links changes very fast due to mobility of the vehicle. Therefore transmission of alert message quickly is an important aspect of it. There are several techniques being proposed that claims to achieve quick alert message propagation. But studies shows that MAC frames are of highest priority in VANET. Therefore any top layer protocol does not suit alert message exchange. Hence in this work we propose a unique technique to dissipate alert message by using a special MAC priority frame. MAC layer subscribe to mobility state change. When congestion or an accident scenario is detected by means of acceleration becoming zero, application layer immediately transmits notification. MAC also subscribes to the same notification board. Hence once alert message is triggered it switches the channel to highest priority channel and then appends a special field in the MAC frame. This message is propagated to road side coordinator and from coordinator is transmitted all the vehicles in the range. The work is simulated using Omnet++ 4.2. Results shows that proposed technique can mitigate alert message with significantly low latency and high packet success rate.***

Keywords: Emergency message, dedicated short-range communications (DSRC), Vehicular ad hoc network (VANET), Beacon.

1. Introduction

Vehicular Ad Hoc Network (VANET) is an innovative wireless network that is rapidly developing by the advances of wireless and automotive technologies. VANETs are automatically formed between moving vehicles equipped with either same or different wireless interfaces. VANETs are a good example of a real-life application of the ad-hoc network that connects the vehicles with other close vehicles or other infrastructures on the road. At present, the VANET adopts dedicated short-range communication (DSRC) technology, which is under the process of standardization as the IEEE 802.11p/WAVE standard. The PHY layer of DSRC is an adaptation of IEEE 802.11a and offers data rates from 3 to 27 Mb/s in 10-MHz channels.

In many active-safety applications the drive is to ensure optimized & safer use of the road network. Each active-safety application is meant to deal with a particular safety aspect. These safety messages are real time in nature because they are relevant for a certain time period, so these emergency messages are transmitted with higher priority than beacons. On the other hand beaconing is equally important, for instance consider the highway mishap of some cities during busiest hour which ensures the entire highway will be congested because of which there will be a major breakdown in the communication system.

It is therefore necessary to devise a feasible solution for an efficient beacon exchange for future DSRCs. For a predictable traffic like beacon, time-division multiple access (TDMA) is preferred over contention-based MAC. In fact, a global positioning system (GPS) could be a good foundation for the realization of a suitable TDMA configuration robust to the highly dynamic VANET scenarios.

In addition to safety concerns, VANET can also support other non-safety applications that require a Quality of Service (QoS) guarantee. This includes Multimedia (e.g., audio/video) and data (e.g., toll collection, internet access, weather/maps/ information) applications.

Vehicular networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and stationary nodes called Road Side Units (RSU) attached to infrastructure that will be deployed along the roads as shown in the above Figureure. Both OBU and RSU devices have wireless/wired communications capabilities. OBUs communicate with each other and with the RSUs in ad hoc manner. The architecture of a node is as shown in Figure (1).

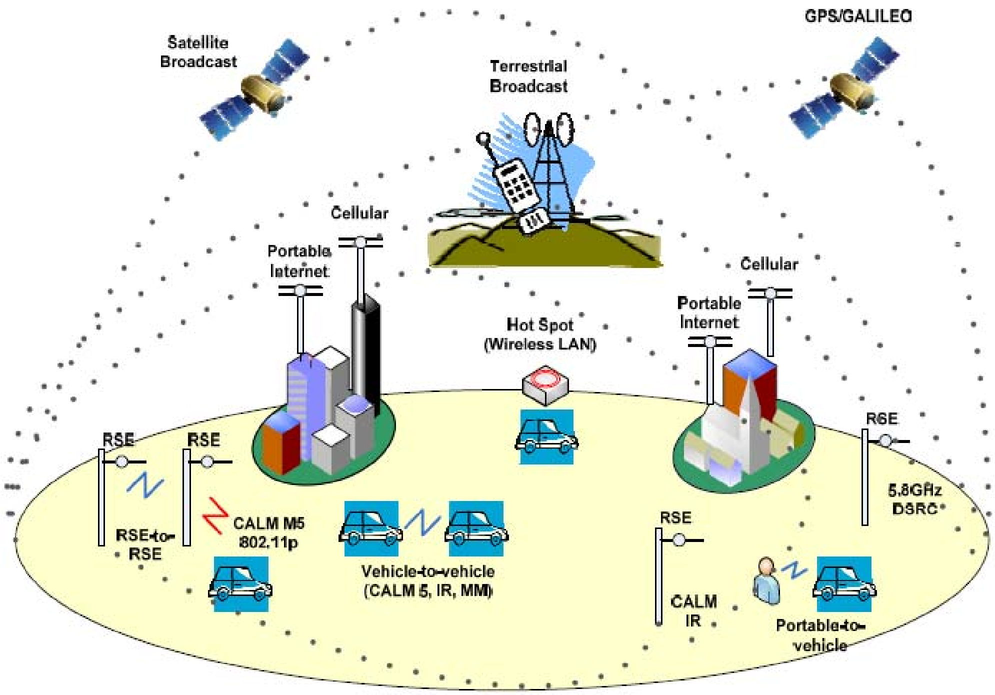

Figure 1: Node in VANET

2. Related work

The basic MAC method of 802.11p is the same as the distributed coordination function (DCF) of IEEE 802.11, which uses a CSMA/CA mechanism. In CSMA/CA, a node transmits only when the channel is sensed as idle. If the channel is 1 The terms "vehicle" and "node" are interchangeably used throughout this paper. sensed as busy, then the node performs random back off. For traffic prioritization, the MAC is extended by incorporating an enhanced distributed channel access (EDCA) mechanism of IEEE 802.11e. EDCA ensures timely dissemination of highly critical emergency messages by assigning appropriate service differentiation parameters. As studied in , EDCA is found to be ineffective in the sense that it does not enforce strict prioritization. Although some enhancements have been witnessed in [1], EDCA is of no use when the traffic consists of only type of safety message.

In this paper [2] author presents Distributed Rate Control for VANETs (DRCV), a distributed light-weight congestion control algorithm tailored for safety messages. DRCV monitors and estimates channel load and controls the packet rate of outgoing periodic packets. A new approach called Fast Drop is adopted to promptly drop the rate of periodic packets when event-driven safety packets are detected. Simulations show the effectiveness of DRCV in increasing packet reception probabilities and achieving efficient channel usage.

In this paper [3] author presents a class of routing protocols called road-based using vehicular traffic (RBVT) routing, which outperforms existing routing protocols in city-based vehicular ad hoc networks (VANETs). RBVT protocols leverage real-time vehicular traffic information to create road-based paths consisting of successions of road intersections that have, with high probability, network connectivity among them. Geographical forwarding is used to transfer packets between intersections on the path, reducing the path's sensitivity to individual node movements. For dense networks with high contention, we optimize the forwarding using a distributed receiver-based election of next hops based on a multi criterion prioritization function that takes non uniform radio propagation into account. We designed and implemented a reactive protocol RBVT-R and a proactive protocol RBVT-P and compared them with protocols representative of mobile ad hoc networks and VANETs. Simulation results in urban settings show that RBVT-R performs best in terms of average delivery rate, with up to a 40% increase compared with some existing protocols. In terms of average delay, RBVT-P performs best, with as much as an 85% decrease compared with the other protocols.

In this paper [4] author presents an analytic model is proposed for the performance evaluation of vehicular safety related services in the dedicated short range communications (DSRC) system on highways. The generation and service of safety messages in each vehicle is modeled by an M/G/1 queue. A semi-Markov process (SMP) model is developed to capture contention and back off behavior in IEEE 802.11 broadcast ad hoc networks. Furthermore, this SMP interacts with the M/G/1 queue through fixed point iteration. Based on the fixed-point solution, performance indices including transmission delay and packet delivery ratio (PDR) are derived. Hidden terminal problem is taken into account for the PDR computation. Analytic-numeric results are verified through extensive simulations under various network parameters. Compared with the existing models, the proposed model is more general and accurate.

In this paper [5] author presents the medium access control (MAC) method of the upcoming vehicular communication standard IEEE 802.11p has been simulated in a highway scenario with periodic broadcast of time-critical packets (so-called heartbeat messages) in a vehicle-to-vehicle situation. The 802.11p MAC method is based on carrier sense multiple access (CSMA) where nodes listen to the wireless channel before sending. If the channel is busy, the node must defer its access and during high utilization periods this could lead to unbounded delays. This well-known property of CSMA is undesirable for time-critical communications. The simulation results reveal that a specific node/vehicle is forced to drop over 80% of its heartbeat messages because no channel access was possible before the next message was generated. To overcome this problem, we propose to use self-organizing time division multiple access (STDMA) for real-time data traffic between vehicles. This MAC method is already successfully applied in commercial surveillance applications for ships (AIS) and airplanes (VDL mode 4). Our initial results indicate that STDMA outperforms CSMA for time-critical traffic safety applications in *ad hoc* vehicular networks.

In this paper [6] author introduces VeMAC, a novel multichannel TDMA MAC protocol designed specifically for a vehicular ad hoc network. The network has one control channel and multiple service channels. On the control channel nodes acquire time slots in a distributed way, while on the service channels nodes are assigned time slots in a centralized manner. VeMAC decreases the probability of transmission collisions caused by node mobility by assigning disjoint sets of time slots to vehicles moving in opposite directions and to road side units. Analysis and simulation results are presented to demonstrate the efficiency of VeMAC and compare it to ADHOC MAC, an existing MAC protocol based on TDMA. It is shown that, for the same number of contending nodes and available time slots, nodes can acquire time slots on the control channel much faster in VeMAC than in ADHOC MAC, when the number of available time slots is sufficiently larger than the number of contending nodes.

In this paper [7] author demonstrate the importance of transmit power control for avoiding saturated channel conditions and ensuring best use of the channel for safety-related purposes. We propose a distributed transmit power control method based on a strict fairness criterion, D-FPAV, to control the load of periodic messages on the channel. The benefits are twofold: i) bandwidth is made available for higher priority data like dissemination of warnings; ii) beacons from different vehicles are treated with 'equal rights' and best possible reception under the available bandwidth constraints is ensured. We formally prove the fairness of the proposed approach. Then we make use of the ns-2 simulator significantly enhanced by realistic highway mobility patterns, improved radio propagation and receiver models, and the IEEE 802.11p specifications, to show the beneficial impact of D-FPAV for safety-related communications. We finally put forward a method, EMDV, for fast and effective multi-hop information dissemination of event-driven messages and show that EMDV benefits of the beaconing load control provided by D-FPAV with respect to both probability of reception and latency.

In this paper [8] author presents the performance of the proposed DCC algorithm and observe that the nominal parameters in DCC are unsuitable in many scenarios. Using transmit power control as an example, we develop a simple rule within the DCC framework that can significantly improve the safety packet reception performance with increasing densities. The DCC algorithms are fully compatible with the IEEE 802.11p standards and *asynchronous* in nature. A parallel approach to handle high device densities is a slotted *synchronous* MAC, where time is slotted based on GPS synchronization and each transmitter contends for a set of recurring time slots (or channels) with periodicity matching the required safety message periodicity.

In this paper [9] author presents the use of IEEE 802.11e for priority based safety messaging for Inter-Vehicle Communications (IVC) in Vehicular Ad-Hoc Networks (VANET). The message priorities, which are assigned based on message urgency, are associated with different quality of service in terms of average delay and normalized throughput. We investigate the use of IEEE 802.11e to provide priority based service differentiation. To increase the communication reliability we also apply a repetitive transmission mechanism that provides proportional reliability differentiation for each prioritized message. We evaluate the performance of our proposed protocol using OPNET Modeler, in terms of average delay and normalized throughput as a function of the number of repetitions, number of vehicles, bit error rates, data rates, percentage of priority 1 vehicles and packet size.

In [10], a clustering and OFDMA-based MAC protocol is proposed, which allows nodes to dynamically form clusters. Cluster heads are elected based on their stability on the road. Using OFDMA, each cluster is assigned a set of subcarriers that are different from the neighboring clusters to avoid hidden terminal problems. The protocol relies on a learning mechanism to maintain the cluster topology. It increases reliability and reduces delay for safety messages. As the size of the cluster is twice the communication range, in realistic scenarios, the status message of the cluster head might not be received by all vehicles located in the cluster. In addition, because of the limited number of subcarriers allocated per cluster, the protocol may not support high density of vehicles with large packet sizes.

3. Problem statement

In the current VANET scenario, congestion in the communication channel has emerged as a serious problem as it affects the performance of active-safety systems. When a great number of vehicles send beacons at a higher frequency (e.g.,10Hz) or multiple event-driven messages are transmitted, the bandwidth can be exhausted very easily. As a consequence, a significant number of packet collisions occur. In the case of an emergency (e.g., accident) scenario, if the channel is already congested, then the highly life-critical event driven messages being deprived of channel access are either lost or delivered to the intended recipients with a much higher delay. Although having lower priority, beacons provide vehicles with knowledge of their surrounding environment and assist in taking safety actions such as detecting a possible collision. Thus, loss of beacons also has a significant impact on the safety of a vehicle. Because of the serious implications of the congestion phenomenon, it is, therefore, necessary to keep the channel free from congestion.

4. Methodology

Overall System is presented in Figureure (2). Nodes periodically broadcast their position data using probabilistic broadcast. Probabilistic broadcast sends the packets with probability P where P depends upon probability of success of previous packet. Data packets are of low probability. Advantage of probabilistic broadcast is no routes are needed to be exclusively maintained between any pair of nodes and nodes exchange position among each other and with road side unit with best probability transmission.

However critical messages need to be immediately transmitted such that every node can be notified on time. We simulate the congestion scenario by conFigureuring an accident in any node at a specific time instance. At time Ts, conFigureured node's speed becomes zero. It needs to immediately notify the nodes which are behind it about the accident such that nodes can suitably adjust their speed. Once accident is cleared, another notification must be generated so that the vehicle can start increasing their acceleration. The objective is to propagate both these messages with the quickest possible time and to reach most number of nodes.

There can be either coordinated or uncoordinated message propagation. The advantage of coordinated message is that the coordinator can reach most number of nodes in a zone. Therefore in this work we propose a coordinated transmission of the message.

First the node that meets the accident (or first congestion node) generates a congestion alert. MAC subscribes to any such alerts. Therefore MAC immediately switches the channel to priority channel. Then it appends a special accident notification field. If MAC already had packets to schedule, it transmits the existing packet with new priority and MAC frame such that the node does not have to wait till the application layer generates a fresh message containing accident information.

If no higher layer packet is available at the time of alert, MAC appends the field in MAC probe packet and transmits. Once the packet is received by the coordinator, it sends broadcast message with highest probability and priority. Therefore the message is received by all the nodes in the region.

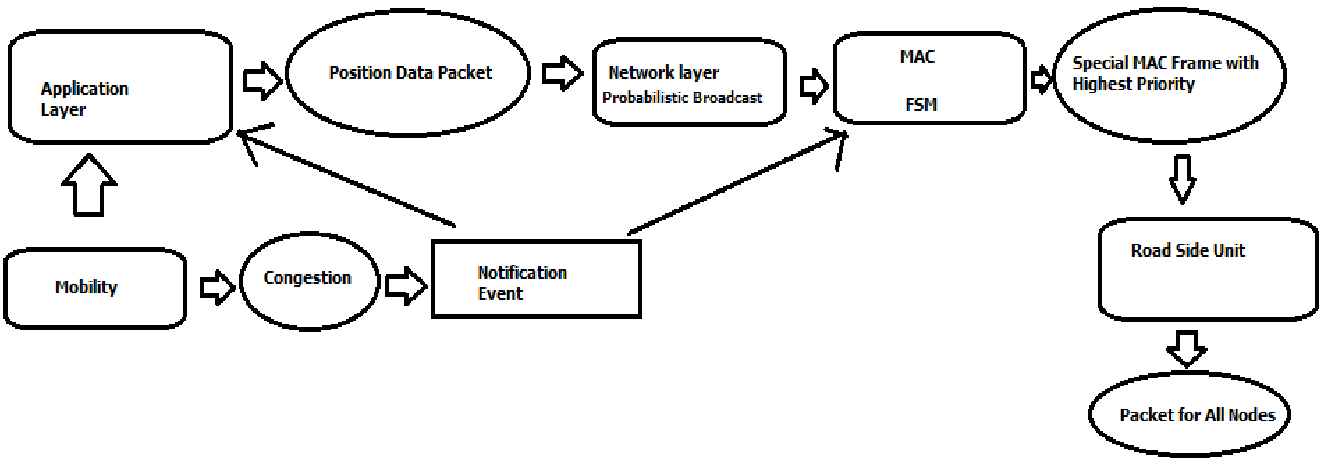

Figure 2: Proposed system

The contribution of the work is to tap the mobility alert from MAC layer and prioritizing the transmission immediately. Because MAC's handling of notification is independent of application layer and because MAC frame are highest priority packets in the network, alert message is propagated at the quickest time. Also due to coordinator, the message reaches to maximum nodes.

5. Simulation results

As simulation time increases, number of nodes increases. Therefore probability of collision is high. But proposed system enables the network to transmit packets with equal probability even under high load. Hence received packet also increases with simulation time. The flat region in Figure (3) represents the time when packet collision was maximum. It can be seen that the network can recover from the loss quickly.

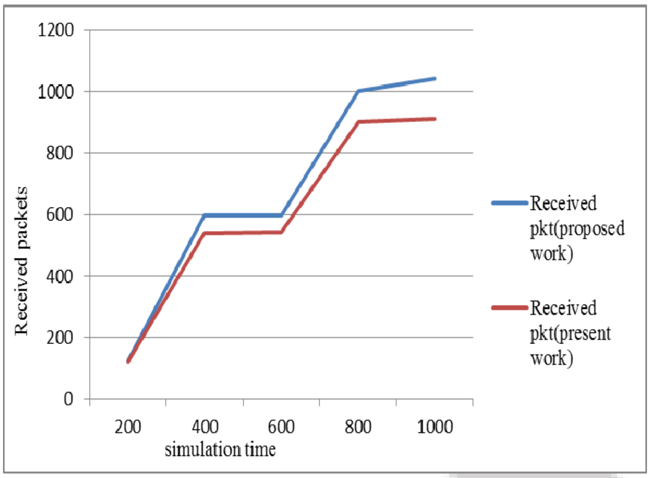

Figure 3: simulation time v/s Received packet

When accident duration increases, more nodes are stationary. Hence chances of collision and packet loss increases. But the proposed system attains high packet rate as shown in Figure (4) even when accident duration is high due to coordinated priority alert transmission.

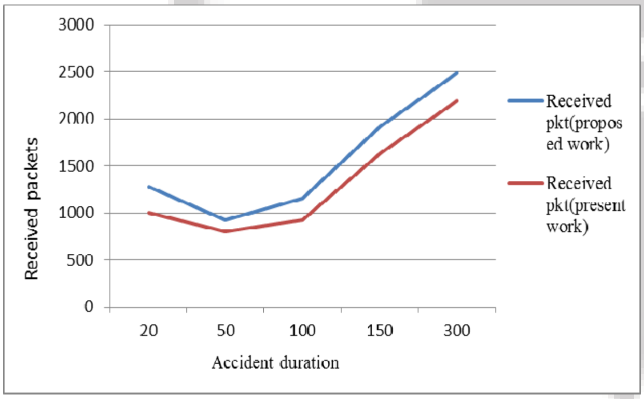

Figure 4: Accident duration v/s Packets received

It can be seen from Figure (5) that even if the accident duration increases, the collision at the channel does not increase. Generally when more number of nodes are in stationary and attempts to transmit packet simultaneously, chances of losses are maximum. However proposed system attains the objective with the help of priority frame. When such packets with priority MAC frames are generated, other nodes back off, allowing the alert messages to be transmitted with minimum collision.

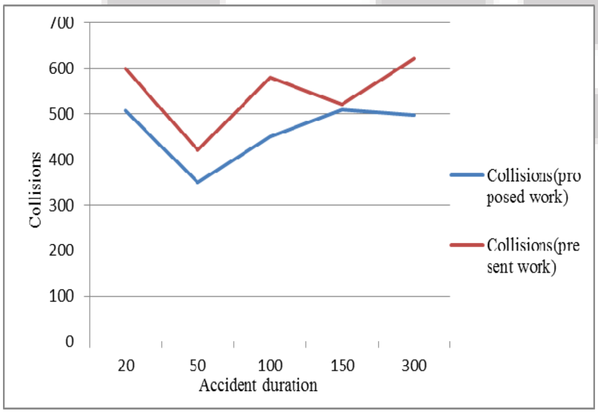

Figure 5: Accident duration v/s Collisions

The below Figure (6) shows that even though accident duration is increased, co2 emission does not increase. This means that the nodes are notified in time so that many vehicles can turn off their engine to save fuel. Due to this the CO2 transmission is also minimum.

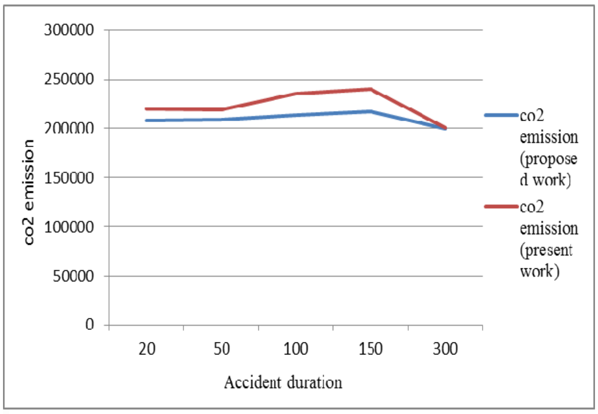

Figure 6: Accident duration v/s co2 footprints

As simulation time increases, number of nodes increases and the system enables the network to transmit packets with equal probability because of which the latency increases. But the proposed work enables the packet reception to increase and latency to decrease as shown in Figure (7).

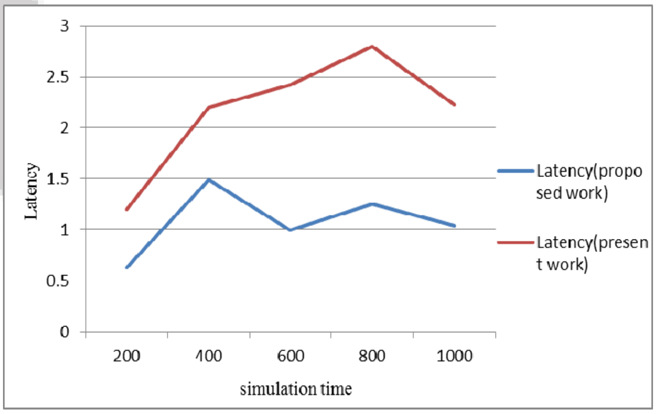

Figure 7: Simulation time v/s Latency

6. Conclusion

VANET is the answer to modern problems of city traffic management. It is being successfully experimented in real time in several places in the world. There are several techniques being proposed for a suitable communication in VANET. Critical message transmission still remains a big challenge in VANET. In this work we have proposed a unique technique for quick and successful packet transmission of critical messages with minimum loss and maximum reach ability. Results show that the proposed system can solve the critical traffic congestion problems through quick and reliable notification system.

7. Future scope

This technique can be further extended by incorporating the dynamic partitioning of beacon interval to enhance the efficiency and fairness of using multiple data rates for beacons. Apart from that, an analytical investigation can be performed.

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