RSU Assisted Channel Allocation in VANETs

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Abstract

Safety and non safety related VANET messages have localized spatial scope and limited time relevance. A MAC protocol must ensure timely delivery of such messages with high reliability over a shared wireless medium. The Vehicles moving on the road form a fluid strait jacketed topology. In this paper, an RSU assisted channel allocation protocol has been proposed to minimize channel allocation time and management overhead. An RSU divides the limited bandwidth allocated to a region into prefixed overlapping spatial clusters and the channel in each cluster is divided into time slots. A time slot is allotted to a vehicle in accordance to the priority of the request and availability of the channel. Simulation results indicate that the allocation scheme is able to deliver packets within the stipulated time with high reliability for different vehicle speeds and density for channel allocation based on three overlapping clusters. Moreover, the technique does not suffer from the hidden and exposed node problem during communication.

Keywords: Medium Access Control (MAC) Protocol, Channel Allocation, Frequency Reuse, Vehicular Ad Hoc Network (VANET), Road Side Unit (RSU)

INTRODUCTION

Technological advances in wireless network have contributed to develop the safety communication systems to avoid congestion and road accidents. High density and speed of vehicles is leading to a marked rise in fatal collisions on the road. An inefficient vehicular communication system can cost a number of lives, wastage of a large volume of fuel, and time. VANET is a network of vehicles moving on the road. The vehicles form small sets of ad hoc networks around fixed road side units (RSUs) that aid in network formation and communication. Vehicles can directly either communicate with each other or with the RSU over the shared wireless medium. Inter RSU communication is over a fixed channel. The motivation behind VANET communication is safety, comfort and eliminating excessive cost due to vehicle collision and traffic jams on the road. However, in principle, cost caused by accidents are avoidable by deploying local warning systems and exchanging traffic and vehicle profile information between

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neighboring vehicles through wireless communication between vehicles and roadside units (RSUs). Vehicles can inform about their intention to other vehicles before leaving road. Similarly vehicles coming towards the road intersection can send warning message to the vehicles already in intersection to avoid any collision. VANET not only improves road safety, but also provides several benefits like helping to manage road traffic while avoiding traffic jams that always results in wasting of fuel and time. Avoiding the traffic jams on road contribute to reducing air and sound pollution. VANET also contributes for human comfort by supporting many types of new comfort applications. VANET communication integrates information and communication technologies within the infrastructure region to manage road traffic in efficient manner besides minimizing vehicle collisions and congestion on the roads and improve the communication reliability.

RELATED WORK

Vehicular networks are experiencing rapid growth and evolution under the increasing demand of vehicular traffic management, network connectivity and reliable communication. The amount of information is to be dramatically increasing in the vehicular network. Infected by high mobility, intermittent connectivity, and unreliability of the wireless channel, it is challenging to satisfy the need for massive data transmission in vehicular networks. In such a case, MAC becomes the most critical segment in the reliable delivery process of emergency packets. There are several studies available for efficient and reliable MAC communication for MANETs. But these MAC protocols for MANETs are not suitable due to high mobility, ephemeral stay period in an RSU region and restricted movement pattern of vehicles governed by road topology, road structure, vehicle classes, driver behavior and attraction points. Currently protocol for frequency channel allocation in VANET communication is not standardized, though many frequency allocation protocols have been proposed. In general MAC protocols for VANETs are classified into two categories. First, contention-based MAC protocols i.e. CSMA, 802. 11 WLAN based MAC protocols and second, contention-free MAC protocols i.e. R-ALOHA based MAC protocols. IEEE 802. 11p standard is being developed for MAC protocol for VANET which is an extension to IEEE 802. 11 standard for wireless LANs. But this protocol is not able provide an upper bound on the channel access delay due to using CSMA/CA as basic protocol for channel access coordination. The upper bound on channel access delay is needed for safety and traffic control application. Delay in channel access for these applications may cost human lives. Moreover IEEE 802. 11p solves the hidden node problem but is not able to solve exposed node problem. Also throughput of this protocol decreases quickly when load increases in the network. The IEEE 802. 11p protocol is not scalable and decreases the performance quickly with load and traffic density. Many protocols and techniques have been proposed to address the shortcomings in the existing standards. ALOHA is the oldest protocol that was proposed for distributed coordinated channel access based on contention. In case of pure ALOHA there is no co-ordination between any station that whenever has data to send than it sends the data and waits for acknowledgement. If it does not get any acknowledgement then it assumes that collision has occurred and backs-off for a random value of time to prevent re-collision. This protocol is simple but not appropriate for VANET because it has very low throughput (18.4%). Slotted ALOHA is an improvement over ALOHA protocol. It divides the time frame into a fix size slots. It imposed restriction on all the transmitting stations to transmit their data in the start of a slot only thus reducing the
number of competing stations for transmission. It halves the vulnerable period of pure ALOHA thus doubles the throughput. The disadvantage of Slotted ALOHA is that its throughput is low (only 36.8%). It also requires the nodes to be synchronized. The low throughput and no upper bound on channel access delay also makes this protocol unsuitable for VANETs. Reservation—ALOHA protocol\(^8\,^9\) a transmitting station monitors the slots in a frame and when it finds a free slot then it reserves that slot. After completing the reservation, the terminal provides its own data once in each frame. The slot is reserved until the station transmits it’s all data. RR-ALOHA\(^10\,^11\), is based on R-ALOHA and uses distributed slotted frame structure with dynamic TDMA mechanism. The limiting factor of this protocol is that it does not utilize the wireless medium efficiently\(^12\,^13\). In VANETs, the node movements are limited by roads and traffic rules, directional antennas\(^14\) can aid in reducing interference and collisions with ongoing transmissions over neighboring vehicular traffic\(^15\). By using directional antennas, transmission collisions can be reduced and channel transmission reuse can be increased. They can theoretically improve the performances of the existing MAC protocols, in particular for VANETs, but unfortunately, directional antenna systems still seem too complex and hard to manage for field implementations\(^16\). Other MAC protocols have also been proposed to study spectrum access in wireless networks. In multi-channel MAC, the channel allocation process takes place on every beacon interval for the concurrent transmissions. The focus is to let multiple parallel communications take place in the same region simultaneously; each on distinct channels\(^17\). Hardware-constrained cognitive MAC protocol opportunistically allocates the spectrum which is not in use by the primary users. Each device senses the spectrum and selects the best channel for each transmission\(^18\). A cognitive MAC for VANET (CMV) integrates two aspects of spectrum access at both long-term and short-term time scales and copes with the highly dynamic channel condition in vehicular communications. For long-term spectrum access, CMV enhances the MAC capacity via concurrent transmission using cognitive radio. Throughput of CMV is larger than the existing multi-channel MAC protocols up to 72%\(^19\). The Decentralized Location Based Channel Access Protocol for vehicle to vehicle communication (DLCAP) addresses the problem of frequency channel reuse in a VANET. The efficient allocation of frequency channels in an ad hoc network permits the ad hoc network to become more scalable. The protocol proposes the Location Channel Access (LCA) to assign a channel to a node in the network based on its geographic position. The protocol proposes to assign channels dynamically without the central controller element based on the location of the vehicle. However, throughput is poor as compared to other protocols\(^20\). DSRC protocol address the need to give safety messages a higher priority than non-safety messages. MAC protocol is developed that based on 802.11a which allows messages to be prioritized. The DSRC protocol was simulated using the Friis and Tworay models. The protocol addressed the need of creating a protocol to send safety messages in DSRC with varying priorities. A vehicle should be able to collect messages from 140 vehicles in its communication range within 200 meters. The average time taken by a driver for reaction to an accident is 700 ms. Presently DSRC protocol provides the standard for vehicular communication\(^21\,^22\,^23\). The most of the MAC protocols of the WAVE system is based on IEEE 802.11. It uses Distributed Coordination Function (DCF) and Enhanced Distributed Channel Access (EDCA). These functions have drawbacks in supporting throughput-sensitive non-safety applications in VANET. In order to address the MAC problem, Vehicular MESH Network (VMESH)
protocol is specially developed for the Control Channel (CCH) and Service Channels (SCHs) for WAVE. In VMASH protocol, a synchronized and distributed beaconing scheme is used for neighborhood awareness and dynamic resource reservation on Service Channels. The advantage of VMESH protocol is in terms of throughput-sensitive non-safety applications in VANET as compared to the current WAVE MAC\textsuperscript{24,25}. In CMAC protocol, the channel allocation and management is transferred to the RSU to obviate channel contention for reliable delivery of messages. The frequency reuse increases the available bandwidth and reduces the waiting time of a node for channel allocation. The throughput of the CMAC protocol as compared to the other protocols is high even when the number of vehicles is high. High packet reception ratio also indicates the efficacy of the protocol for high reliability low delay delivery of messages in a VANET environment. The CMAC protocol may not scale at high vehicular traffic and would not work in ad hoc mode in areas where there are no RSUs\textsuperscript{26}. The Reliable Busy Tone Multiple Access (R-BTMA) MAC protocol is based on the BTMA protocol. The major contributions of this protocol are the original emergency message and its copies are treated separately by assigning different priorities. R-BTMA protocol maintains the Neighboring Information Table (NIT) for MAC communication. NIT, records the MAC addresses of transmitting nodes, is built to eliminate the transmission redundancy in the network. The R-BTMA protocol achieves a better performance on the delay of the emergency message transmission. All nodes with emergency packets waiting for transmission can contend the channel with a random back-off timer and only the node with higher priority emergency message can interrupt the current transmission. Hence the communication is collision free in the network and enhances the performance of the protocol significantly in terms of transmission delay\textsuperscript{27}. Apart from delay, packet loss and security are also serious problem for safety message dissemination in VANETs. The neighbors of a vehicle in a VANET usually change all the time in the network. Current link layer protocols for safety message suffer from significant packet loss, scalability and security challenges. CSMA approaches produce excessive transmission collisions at high vehicle densities and speeds. Similarly time slot allocation approaches need for a fixed infrastructure, a high number of control messages, or poor bandwidth utilization, particularly in low density and traffic scenario. The Adaptive Space Division Multiplexing (ASDM) protocol requires no control messages, provides protection against security challenges, significantly improves bandwidth utilization, and automatically adjusts the time slot allocation in response to changes in vehicle densities and speeds. ASDM protocol also provides message delivery guarantees is contrasted with the existing MAC protocols\textsuperscript{28}. Authors in\textsuperscript{29,30,31}, proposed a cross layered MAC protocol for supporting the fast propagation of broadcast messages in a VANET. Cross-layered MAC protocol and clustering scheme efficiently broadcasts alert messages in the VANETs, based on Dynamic Backbone Assisted MAC protocol and Fast Multi-hop Forwarding protocol. This protocol is compliant with IEEE 802.11 DCF systems. The cross layered MAC protocol provides the advantages in terms of performance, reliability, and overhead reduction from the current MAC protocols. Performance of this protocol also presents the effectiveness of the mutual support of proactive clustering and MAC protocols for efficient dissemination of broadcast messages in VANETs. In paper\textsuperscript{32}, authors proposed the Distributed MAC protocol for emergency messages in VANET. The existing MAC protocols do not support strict packet-level priority scheduling and lossless medium access in a distributed way. This MAC scheme realizes
timely and lossless medium access for emergency packets in distributed way. In a fully distributed way, this protocol introduces preemptive priority scheduling at the MAC sub layer to serve emergency packets in VANETs. Moreover, it supports multiple levels of strict priority for emergency packets. CSMA/ECA is a modification of CSMA/CA protocol which suits the VANET environment. CSMA/ECA protocol accesses the performance in single hop ad-hoc networks and it uses deterministic back-off values after successful transmissions, which reduces the chances of collision in the network. In order to validate the goodness of CSMA/ECA, it delivers higher performance for the most common kinds of traffic: elastic flows and rigid flows. The performance of CSMA/ECA have been compared with CSMA/CA, it provides higher throughput when elastic flows are considered. Regarding rigid flows, CSMA/ECA allows for a larger number of simultaneous flows before reaching the congestion condition. In a mixed scenario that includes both rigid and elastic flows, CSMA/ECA still attains higher throughput for the elastic flows and increased protection for the rigid flows in the vehicular networks. Enhanced Distributed Coordination Function (EDCF) is proposed for MAC protocol in VANETs. EDCF assigns four different priority classes for incoming packets at each node which are called access categories (AC). Each AC has its own channel access function when compared with 802.11 Distributed Coordination Function (DCF) in which all packets exploit the same access function to acquire the channel. Different access functions for different categories means assigning different delay times, different minimum contention windows, and different number of back-off stages for each type of service. This protocol shows improvement in providing QoS when compared with 802.11 DCF for vehicular environment. In the present work, RSU assisted frequency allocation protocol has been proposed to address the issues of hidden/exposed terminal, throughput and safety message delivery delay by transferring most of the control signaling to the RSU and maintaining a priority queue.

PROBLEM FORMULATION

A MAC protocol must satisfy unique needs of a VANET in an environment constrained by specific characteristics i.e. high mobility of vehicles, partial participation of the road side infrastructure, motion of the vehicles in predetermined road topology, small subsets of vehicles that form independent ad hoc network in an RSU region and a tightly time bound delivery of critical messages. Efficient MAC communication can inform vehicles about other vehicles approaching from other directions or dangerously turning of the vehicles on the road in prescribed time manner. In general, the amount of information to be transmitted is relatively small (the movement information of each vehicle), but the transmission reliability is fundamental. Active Safety applications for VANETs need to establish reliable communications with minimal transmission collisions. Vehicles move on predetermined straight jacket roads at high speeds and enter/exit RSU region in short intervals of time. At a time, the number of vehicles in an RSU region can vary rapidly from a few vehicles to a large number of vehicles. The stay period of vehicles in an RSU region is very short interval of time. A protocol must be distributed or should require partial RSU support with an efficient handoff from one RSU to another to satisfy these characteristics. The motion of the vehicles is confined to the roads and directional antenna would be suitable for communication via RSUs. The nodes broadcast radio frequencies with transmission channels, each one considered as a common medium over which two neighboring terminals
cannot transmit simultaneously because a transmission collision occurs. So, in order to efficiently share the medium, MAC protocol is needed and is beset by contention delay. However, a protocol must ensure that critical messages are delivered within a prescribed time frame. The protocol must not suffer without the hidden/exposed terminal or deafness problem to ensure reliable message delivery. The MAC protocol should be bandwidth efficient and scalable to cater to the large variation in the number of vehicles in an RSU region. Finally, since the road network is spread over a large geographical area, the protocol must be able to function with synchronization or without any synchronization. Thus, the main problem in the design of a MAC protocol is the time bound reliable delivery of critical messages in a bandwidth constrained shared wireless channel with nodes moving at high speed. The efficient MAC can provide a more stable communication than a solution using fixed infrastructure.

**CHANNEL ALLOCATION PROTOCOL**

The RSU assisted frequency allocation protocol adopts a centralized approach by shifting the control and management of the wireless channel to the RSU. RSU has sufficient computational and storage capacity and is equipped with two directional antennas calibrated according to the structure of highway to provide efficient coverage. An RSU region is divided into rectangular clusters. The area between two overlapped cluster regions represents the inter-cluster handoff regions. The whole frequency spectrum is divided into a number of frequency bands separated by guard bands. Each frequency band is divided into eight fixed time slots of equal size separated by guard time. A logical channel consists of a frequency band plus a time slot. All the logical channels are divided into four parts i.e. Control Band (CB), Frequency Band 1 (FB1), Frequency Band 2 (FB2) and Inter Handoff Band (IHB). In Control Band (CB), group of channels to be used for channel allocation and control signaling. Safety messages are also broadcast over this band. Frequency Band 1 (FB1) is a group of channels to be used by vehicles for data transmission. Frequency Band 2 (FB2) is a group of channels to be used in clusters adjacent to the channel using FB1 and in Inter Handoff Band (IHB), group of channels to be used by vehicles in the handoff area.

An RSU broadcasts periodic beacon message with its identity and location. When a vehicle comes into the coverage area of an RSU and receives its broadcast, it calculates its relative position and sends the association request to register in the RSU area. When a registered vehicle wants to communicate, it requests a channel by sending a channel request packet to the RSU over control channel. The request message contains the source and destination id, application type, current speed, timestamp, relative distance and direction of motion etc. RSU determines the cluster id of the vehicle and the priority of the request packet. For this, the RSU maintains two different queues of channel request packets and gives higher priority to the safety application requests. A non safety application request list is processed only when there is no pending request packet in the safety application request list. If the destination vehicle is already busy or is not in communication range then no channel is allocated to the vehicle. If the destination vehicle is free or if request is for a broadcast, transmission slots are allocated to the vehicle by sending a clear request. The slot remains allocated until the vehicle informs the RSU that the transmission is over or the vehicle leaves the current cluster. As soon as RSU gets any packet informing about completion of transmission it marks the channel as free in its information base.
**PROTOCOL OPERATION**

RSU assisted frequency allocation protocol operates on the vehicles and RSUs. Each vehicle continuously monitors the control channel. When a vehicle has information for transmission, it determines the type of application that has generated the data and creates a channel request packet. The type of application is indicated in the packet using application four bit id field. This request packet is sent to the RSU over the control channel. The RSU maintains a channel allocation matrix that keeps information about the currently assigned and free channel information. It also maintains a table that stores the information about which channel is given to which particular source vehicle along with time stamp and the mode of transmission (broadcast/unicast). The transmitted packets from vehicles are multiplexed in a frame.

RSU assisted frequency allocation protocol is able to solve hidden and exposed node problem. The RSU maintains a table about which particular node pairs are communicating on which particular channel. When a vehicle makes a request to RSU to communicate with its neighbor who is already in communication with other vehicle, RSU refuses to allocate any channel to the requesting node. This solves the hidden terminal problem. Similarly if any exposed node makes a channel request to RSU it will be assigned a different frequency channel that will not conflict with its neighboring node already in communication with nodes two hops away. RSU assisted frequency allocation leads to efficient utilization of frequency spectrum by avoiding contention based reservation. A separate priority queue is maintained for the channel request packets of safety and non safety applications. The major limitation of this frequency allocation protocol is that it does not work in absence of the RSU. Since the number of clusters in an RSU is prefixed, the performance of the protocol may drop when there is congestion or the vehicular density is unduly high.

**SIMULATION AND RESULTS**

The evaluation of RSU assisted frequency allocation protocol requires the generation of the topological structure of an RSU region and the vehicular traffic. The RSU assisted frequency allocation protocol simulated over this traffic model are:

**A. Vehicle Movement Pattern Generation**

Vehicles move in bidirectional single or multi lanes on the road with different speeds and accelerations. They also turn in different directions at junctions. There are different classes of lane on the road as per the speed limits to be followed vehicles i.e. low and high speed lane on the road. Each vehicle starts moving from definite segment, travels on the road and can change its lane or overtake another vehicle. After reaching destination or at traffic lights, vehicle stops for a pause of some time and then repeat the same process i.e. randomly and predefined next destination on the road. This road pattern includes the features of safe driving i.e. speed limits & safety distances. This road pattern of a vehicle on the segment of the road follows some restriction on traveling behavior of vehicle. A vehicle must proceed on predefined paths and follow traffic rules. The density of the vehicular traffic also varies from one place to another and with respect to time.

**B. Network Simulation**

For generation of realistic vehicle movement pattern, open source simulator NCTUs has been used\textsuperscript{35}. It is used to define roads, number of lanes per road, turning ratio of the vehicles at a junction, vehicle speed at junctions and traffic lights on the road or junction. The generated road topology and other details like trip
information, turning ratio of vehicles at junctions and number of vehicles are input to NCTUns. The RSU assisted frequency allocation protocol is simulated in NCTUns for the traffic pattern. Fig. 1 provides the snapshot during the process of movement pattern generation. This generated mobility trace file used by the network simulator NCTUns.

![Fig. 1. Snapshot of NCTUns Generated Movement Pattern](image)

C. Results

The proposed RSU assisted frequency allocation protocol simulation is done using 5, 10, 15, and 20 vehicles for 6 minutes with above described topology. An RSU equipped with directional antenna is put on the highway which has coverage range up to 1000 m. All the vehicles coming from different sources pass through highway which is a four lane highway system. The experiment is repeated with different cluster sizes and the packet reception ratio is calculated using generated wireless trace file of NCTUns. The graph between number of vehicles and packet reception ratio at different vehicle speeds are shown in Fig. 2.

![Fig. 2a. Number of Vehicles v/s Packet Reception Ratio](image)

Table I contains the road and communication parameters used for creating road topology for movement pattern generation and the network simulation.

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<thead>
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<th>Table I. Simulation Parameters</th>
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<td><strong>Number of Vehicles</strong></td>
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<td><strong>Data Rate</strong></td>
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<td><strong>Packets</strong></td>
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<td><strong>Traffic Type</strong></td>
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<td><strong>Packet size</strong></td>
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<td><strong>Packet Generation Rate of Vehicle</strong></td>
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<td><strong>Transmission Range of RSU</strong></td>
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<td><strong>Transmission Range of Vehicle</strong></td>
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<td><strong>Vehicle Speed Range</strong></td>
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<td><strong>Simulation Time</strong></td>
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Consider the cluster size of 250 m as shown in Fig. 2. Fig. 2(a) shows that the packet reception ratio is maximum with 5 vehicles. Vehicles are able to communicate efficiently with each other as compared to the RR-ALOHA protocol which cannot utilize the wireless medium efficiently. As the number of communicating nodes (number of vehicles) increases, the packet reception ratio or throughput decreases continuously in the proposed RSU assisted protocol. This means that the performance of the RSU assisted protocol is better when the number of vehicles is low in the cluster.
The maximum throughput is 73% when the number of communicating nodes is 5 nodes and the minimum throughput is 50% when the number of communicating nodes is 20 at speed of 10 ms⁻¹. If the number of communicating nodes increases in the network, the quality of service in RSU assisted protocol is nearly constant as compared to RR-ALOHA where the quality of service reduces drastically with load.

Fig. 2(b) shows that the packet reception ratio is maximum with 10 vehicles at speed of 20 ms⁻¹. Initially the packet reception ratio is 69% with 5 vehicles. If the number of vehicles increases, the packet reception ratio or throughput decreases continuously in the RSU assisted frequency allocation in the network. The minimum packet reception ratio is 56% with 20 vehicles. This shows that in the same cluster size, if the speed of the vehicles increased with gradually increment in the number of vehicle, packet reception ratio decreases. This RSU assisted frequency allocation and utilization of wireless medium is more efficient than RR-ALOHA where the quality of service is more compromised with load.

Fig. 2(c) and Fig. 2(d) also show that for same cluster size, the packet reception ratio is maximum with 10 vehicles at speed of 30 and 40 ms⁻¹. The maximum packet reception ratios at 10 vehicles are 73%. At starting phase of the simulation with 5 vehicles, the packet reception ratios are 70% and 72% respectively. If the number of vehicles increases, the packet reception ratio or...
throughput decreases continuously in the network. The minimum packet reception ratios 52% and 56% respectively with 20 vehicles. This shows that, if the speed of the vehicles is increased with gradually increment in the number of vehicle, packet reception ratio decreases. This RSU assisted frequency allocation and utilization of wireless medium is more efficient than others protocol where the quality of service is more compromised with the load.

The experiment was repeated with different cluster sizes and 20 vehicles to determine the relation between cluster sizes and packet reception ratio (Fig. 3). From the results, it can be observed that for a cluster size of 250 m, the packet reception ratio is approximately 60%. If the cluster size is less than 250 m the packet reception ratio is not significant. The packet reception ratio increases with increase in cluster size because inter cluster interference decreases in the network. For cluster size of 600 m it was found that maximum packet reception ratio is approximately 80% for proposed RSU assisted protocol. Any further increase in the cluster size results in decrease of packet reception ratio up to approximately 50%.

CONCLUSION

A VANET MAC protocol needs to address two issues. One, efficient allocation of limited bandwidth allocated to an RSU region and two, timely delivery of messages over the shared wireless channel. An RSU assisted channel allocation addresses both the requirements in addition to channel maintenance in a loosely synchronized environment. The lack of contention for channel acquisition and priority list at the RSU allows the protocol to ensure timely delivery of safety messages. Non-adjacent clusters allow frequency reuse. The RSU broadcast is heard by all the vehicles in the RSU region and this solves the problem of hidden/exposed terminals and results efficient utilization of the allocated spectrum by avoiding contention. The throughput and delay are only slightly dependent on vehicle speed and density although the cluster size affects the throughput drastically. However, the protocol may not scale to high vehicular traffic and would not work in areas where there are no RSUs.

REFERENCES


22. X. Chen, H. H. Refai, and X. Ma, “A Quantitative Approach to Evaluate DSRC


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