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Research paper

A survey of collision avoidance in TDMA based mac protocols for vehicular Adhoc networks

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Abstract

Vehicular Ad-hoc Network (VANET) is becoming an emerging trend to meet the various demands in real time applications. It is a special kind of MANET that has attracted a lot of attention in the research community in recent years due to its promising applications. Each vehicle can exchange information to inform other vehicles about the current status of the traffic flow or a dangerous situation such as an accident. Each year road accidents cause millions of death and non-fatal injuries. So it is desirable to have some method of communication between vehicles that can warn drivers and passengers. With the help of VANET, vehicles can move in an organized fashion.When two or more nodes occupy the same time slot and drive into each other's communication ranges, a reservation collision occurs. A reliable communication scheme with minimal transmission collision is needed which increases the need for an efficient Medium Access Control (MAC) protocol. However, the design of the MAC in a vehicular network is a challenging task due to the high speed of the nodes, the frequent changes in topology, the lack of infrastructure etc. Recently several Time Division Multiple Access (TDMA)-based medium access control protocols have been proposed for VANETs in an attempt to ensure that all the vehicles have enough time to send safety messages without collisions and to reduce the end-to-end delay and the packet loss ratio. In this paper, we provide an overview of TDMA-based MAC protocols that have been proposed for VANETs that provide a collision free transmission.We focus on the characteristics of these protocols, as well as on their benefits and limitations.

Keywords: *IEEE 802.11P; MAC Protocols; Reservation Collision; VANET; TDMA.*

1. Introduction

Vehicular Ad hoc Networks (VANETs) are primarily designed to improve safety on roads. They can also be used to improve traffic management conditions and to provide on-board infotainment such as Internet access, video streaming, etc. VANET has extra characters and more transmission problems than MANET including real road scenes, high-density distribution of nodes, and rapidly moving nodes. The wireless local area network (LAN) standard, viz. IEEE 802.11 consist of a set of standards. In these standards, IEEE 802.11p is the MAC protocol for VANETs. However, IEEE 802.11p is based on the legacy IEEE 802.11 standard and cannot provide an efficient broadcast service which may cause hidden terminal problems. In addition to IEEE 802.11p-basedMAC protocols, some time division multiple access (TDMA)-based MAC protocols have been proposed to address the broadcast problems. The ad hoc MAC protocol is based on TDMA and can provide efficient broadcast service and avoid hidden terminal problems by letting each node broadcast the status of all nodes in the virtual frames.

VANET Architecture

The communication between vehicles or between a vehicle and an RSU is achieved through a wireless medium called WAVE. The main system components are the application unit (AU), OBU (On Board Unit) and RSU (Road Side Unit). Typically the RSU hosts an application that provides services and the OBU is a peer device that uses the services provided. The application may reside in the RSU or in the OBU; the device that hosts the application is called the provider and the device using the application is described as the user. Each vehicle is equipped with an OBU and a set of sensors to collect and process the information and send it as a message to other vehicles or RSUs through the wireless medium; it also carries a single or multiple AU that use the applications provided by the provider using OBU connection capabilities. The RSU can also connect to the Internet or to another server which allows AU's from multiple vehicles to connect to the Internet.

Data Transmitted from a road side infra-structure to a vehicle could reduce the number of accidents by warning the driver.

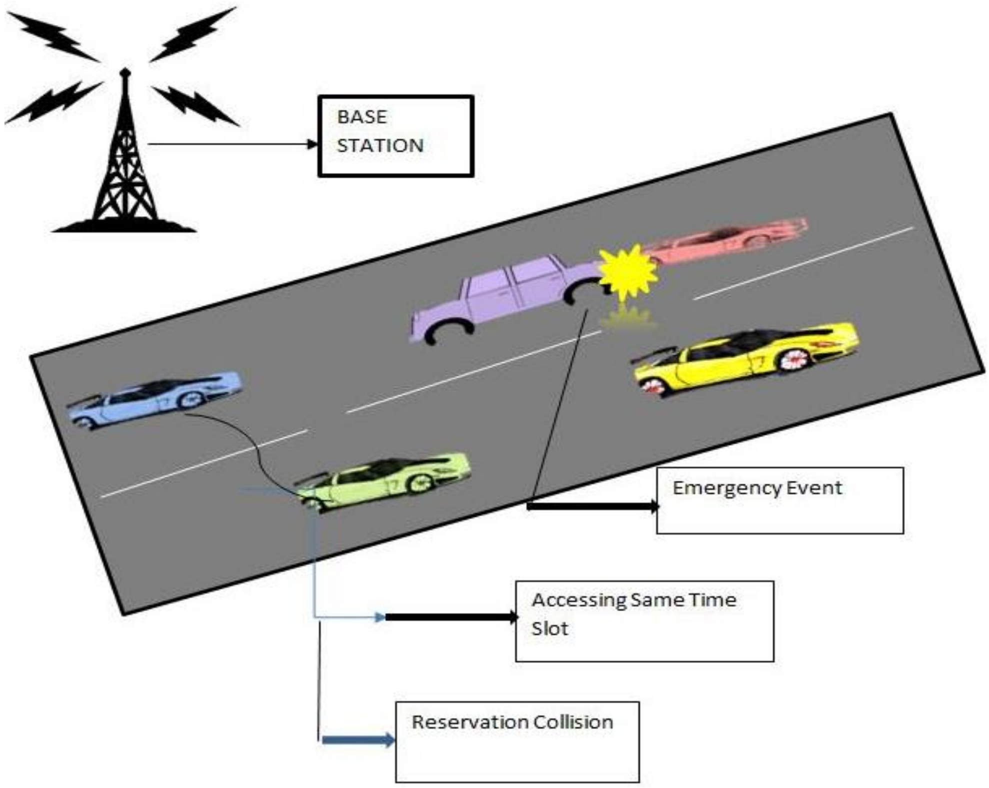

Fig. 1: Vehicular Ad Hoc Network Architecture.

The RSU is a wave device usually fixed along the road side or in dedicated locations such as in junctions or near parking spaces. The RSU is equipped with one network device for a dedicated short range communication based on IEEE 802.11p radio technology, and can also be equipped with other network devices so as to be used for the purpose of communication within the infrastructural network. According to C.C. Communication Consortium, the main functions and procedures associated with the RSU are extending the communication range of the ad hoc network by re-distributing the information to other OBUs and by sending the information to other RSUs in order to forward it to other OBUs.

2. Related work

Collision avoidance in VANET is done by various schemes and each section II,section III and section IV has its pros and cons.

a) GAH-MAC: Game-based TDMA MAC Protocol for Vehicular Network

GAH-MAC [1] is a reservation collision mechanism where, the colliding nodes play games with each other to decide whether to reserve the original slot or a new one. In this way, the time slots are fully used, and the reservation speeds are increased without being controlled by the base stations.

In a VANET, when a reservation collision occurs, every colliding node intends to occupy the time slot to maximize its own throughput. This individual rational behavior conforms to the research field of non-cooperative game theory, whose objective is to maximize individual benefit. This competitive process is seen as a non-cooperative game. This paper uses game theory to analyze progress when colliding nodes reserve the time slots again. This process is essentially a static game of perfect information, and the Nash equilibrium solution is the probability set of the nodes choosing their corresponding strategies.

The mechanism proposed in this paper adds an extra process for colliding nodes to reserve slots again. So the reservation procedure can be appropriate for high-density network. The structure of control message and frame should be modified to enable the colliding nodes to reserve slots again.

b) CCC-MAC: Congestion-Controlled-Coordinator-Based MAC for Safety-Critical Message Transmission in VANETs

MAC (CCC-MAC) [2], is a time-slot-based medium access protocol that addresses beacons and emergency messages. Basically, the network is virtually partitioned into a number of segments. Within a segment, medium access is accomplished by using a time-slot-scheduling mechanism supervised by a local coordinator vehicle. A significant number of vehicles supported by increasing the data rate of a beacon reduce the transmission duration, which, in turn, reduces the beacon load on the channel. Since multiple data rates are available in the DSRC standard, congestion is avoided even in the presence of a significant number of vehicles. However, to achieve a specific communication range, higher data rates require higher transmit powers, which result in larger interference ranges.

c) VEC-MAC: A Multi-Round Elimination Contention based Multichannel MAC Scheme for VANETs

In VEC-MAC the control channel (CCH) interval is divided into three phases: roadside unit (RSU) broadcast phase, safety message broadcast phase and service channel (SCH) reservation phase. Based on this division both the demand of safety-relevant applications and non-safety service applications are satisfied. In addition, through the multi-round elimination contention in the service channel reservation phase collision probability of transmissions significantly decreases and more successful reservations are provided.

d) ETCM: an enhanced TDMA cluster-based MAC (ETCM) for multichannel vehicular networks

ETCM protocol which is based on TDMA slot reservation with clustering of vehicles for multichannel vehicular networks, using single radio vehicular transceiver. The major contributions of the proposed ETCM protocol are: i) the enhanced logical frame structure with allocations of two mini-slots for each vehicle in each synchronous interval (in 100ms) to increase collision-free channel access and reliable time-critical safety message deliveries, ii) enhanced bandwidth utilization of service channels with dynamic reallocations of unused slots for vehicular communications with single radio transceiver, and iii) increased fairness among vehicles by balanced slot allocations even at high traffic load conditions.

e) VeMAC: A TDMA-based MAC protocol for reliable broadcast in VANETs

VeMAC assigns disjoint sets of time slots according to the moving directions of the vehicles and reduce the conflict probability of slot reservation caused by the movement of the vehicles. A hybrid efficient and reliable MAC (HER-MAC) VeMAC employs new techniques for the nodes to access the available time slots and to detect transmission collisions. In the VeMAC protocol, each node must acquire exactly one time slot in a frame on channel c. Once a node acquires a time slot, it keeps accessing the same slot in all subsequent frames on channel c unless a transmission collision is detected .Each packet transmitted on channel c is divided into four main fields: header, announcement of services (AnS), acceptance of services (AcS), and high-priority short applications

f) C-TDMA: A TDMA-based MAC protocol with cooperative diversity

C-TDMA allows vehicle nodes to send safety messages without collision on the control channel within their reserved time slots and to utilize the service channel (SCH) resources during the control channel interval for the non-safety message transmissions. In a cooperative TDMA system, each terminal transmits existing packets, if any in its FIFS buffer during its exclusively

allocated time slot. If the transmission fails, the packet is retransmitted in the following frames until it is transmitted successfully and then cleared from the terminals FIFS buffer.

During slots other than the terminal's exclusively allocated slot within a frame, called overhearing slots, each terminal listens to other terminals' transmissions. At the end of each overhearing slot, there are four possible scenarios: a) the packet overheard is correctly decoded and a positive acknowledgement is received by the terminal; b) the packet overheard is not correctly decoded and a positive acknowledgement is received by the terminal; c) the packet

overhead is correctly decoded but a negative acknowledgement is received by the terminal; d) the packet overheard is not correctly decoded and a negative acknowledgement is received by the terminal.

g) CAH-MAC: cooperative ADHOC MAC for vehicular networks

In CAH-MAC, neighboring nodes cooperate by utilizing unreserved time slots, for retransmission of a packet which fail to reach the target receiver due to a poor channel condition. In this system, nodes reserve their time slots and nearby nodes form a cluster to share a time frame. For cooperation at the link layer, a helper node utilizes an idle time slot to relay a packet that failed to reach the destination in a direct transmission, without affecting the normal (non relay) transmissions. Using idle time slots for the cooperative relay transmissions, the slot reservation of CFR MAC is based on the driving status and traffic flow of each vehicle. It avoids the hidden terminal problem and reduces the merging collisions by assigning different groups of slots to vehicles according to their driving directions.

Carrier-sense multiple access (CSMA) and self-organizing TDMA MAC (CS-TDMA) is proposed in [9], which is a multichannel version of the SOFTMAC protocol.The difference of CS-TDMA with other multi-channel protocols is that the ratio between the control channel (CCH) and SCH intervals is dynamically adjusted according to traffic density. However, access collision and merging collision problems are not studied in [7], [9]. Many improved TDMA-based MAC protocols use the mechanism of cooperative transmission. In [10], cooperative-TDMA (C-TDMA) improves network throughput by enabling cooperative retransmission based on a multiple-antenna system. Cooperative ADHOC MAC (CAH-MAC) [11] enables helper nodes to exploit an unreserved slot for cooperative retransmission. This requires additional overhead, which increases the size of the packet header. A cooperative MAC protocol proposed in [12] uses idle slots to retransmit packets in a multi-hop network. This guarantees throughput performance without extra overhead

h) SCMAC : A scalable and cooperative MAC protocol for control channel Access in VANETs

SCMAC provides communication reliability and protocol scalability. The communication reliability is guaranteed by cooperative beaconing. When broadcasting a beacon, the node embeds the slot state information into the beacon so that its surrounding nodes can determine the availability of each slot. Together with the contention window, collisions are alleviated. The protocol scalability is implemented by the slot access method and the proactive slot reservation. On one hand, the slot access method reduces the average delay by using the smaller beaconing period as the node density is decreasing. On the other hand, the proactive slot reservation always keeps enough idle slots so that more nodes can quickly join the network. Correspondingly, the beaconing period increases and all nodes gain chances to broadcast beacons.

i) A tone-based time-slotted protocol for multi-hop

This Scheme assigns the responsibility of message forwarding to only a subset of vehicles on the road, known as "segment leader," as part of broadcast storm suppression strategy. To avoid the potential interference caused by the safety messages, separate multi-hop time slots are used for the warning messages, which are reserved by a newly proposed out-of-band long range CLEAR tone. Such a tone-based reservation mechanism allows the continuous transmission of the safety messages in the absence of a CLEAR tone, giving rise to a much higher network utilization.

3. Comparative analysis

The Various reservation schemes of VANETs discussed above and are compared in this section based on the mechanism used, success rate and Utilization.

Protocols	Collision	Mechanism	Success Rate	Utilization
GAH-MAC	Vehicular Network	Game based slot reservation	Improved in high density network	Waiting counter is directly related to the utility value of each node. More priority is to reserve original conflict slot
CCC-MAC	Safety-Critical Message Transmission	Pulse based slot reservation	Increased data rate and reduced transmission duration	Higher data rate needed higher transmit power
VEC-MAC	Multichannel Vehicular Networks	Multi-round elimination	Nodes acquires a time slot on channel at a fast rate	The same time slot is accessed in all subsequent frames on the channel.
ETCM	Multichannel Vehicular Networks	Dynamic reallocation of unused slot	Increased collision-free channel access and reliable time-critical safety message deliveries	Bandwidth utilization is improved with the dynamic reallocation of unused time slot
C-TDMA	Cooperative	Cooperative trans-	Each terminal listens to other terminals'	A diversity gain is obtained to im-

	Diversity	mission	transmissions. Even if any transmission fails then it retransmits until it clears the buffer	prove the probability of correct packet reception
CAH-MAC	Vehicular Networks	Neighboring nodes cooperate by utilizing unreserved time slots	Allows the nodes to perform concurrent transmissions to improve throughput	Each node reserve to a time slot to transmit its own packets and does not increase the waiting time of neighboring nodes to access channel
SCMAC	Control Channel Access	Proactive slot reservation	Communication reliability and protocol scalability	Nodes have two states: online and offline. When a node gains the right to access a slot through contention, it becomes online
Tone-Based Time-Slotted Protocol	Multi-Hop	Out-of-band long range CLEAR tone	Vehicles resend the same warning message in one of the next time slots reserved for multi-hop warning message dissemination	Warning messages, vehicles on the highway relay the messages to other vehicles

4. Conclusion

Collision is one of the major issues in VANET at the time of slot reservation. This survey on TDMA based MAC protocols explores the various mechanisms for collision avoidance and analyses them in terms of factors like success rate, bandwidth utilization and the mechanisms used. Contention free MAC protocols consume more energy as well as high data rate is needed for an efficient data transmission. Contention based Multi-channel MAC protocols provide increased collision-free channel access and are well suited for reliable time-critical safety applications. The hybrid protocols provide QoS support for the problems arising due to high mobility, GPS locations and reduce access and merging collisions. To meet the growing need of vehicular networks with large number of nodes, finding mechanisms to ensure reliable, efficient and collision-free transmissions becomes an open research issue.

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