Volume 6, Issue 2, February 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Survey on MAC Protocol for Vehicular Adhoc Networks

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Abstract- In recent years the government, standardization bodies, automobile manufacturers, and academia are being working together for the development of the vehicular adhoc network (VANETs) based communication technologies. For enabling better reliable and efficient communications in VANETs the standards like the IEEE 802.11p or the WAVE (Wireless Access in Vehicular Environment) standard has issued physical (PHY) and medium access control layer (MAC) specifications. This paper surveys recent MAC protocols that has being proposed for Vehicular adhoc Network and also presents a clarification for the various approaches pursued. This paper mainly based on the different MAC protocols that are proposed for reliable and efficient broadcast and transmission of the messages in VANETs. Each routing protocol is discussed and described under appropriate category.

Keywords- Vehicular ad hoc networks (VANETs), medium access control (MAC) protocol, bandwidth utilization, multichannel, beacon, dedicated short-range communications (DSRC), IEEE 802.11p.

I. INTRODUCTION

VANET (Vehicular Adhoc Networks) are important part of Intelligent Transportation Systems (ITS) and is emerging as important technology to provide safety and comfort to the vehicles in transportation systems [12]-[17]. It is special type of mobile adhoc network where there is high mobility of the nodes. The VANETs has two types of communications that is the vehicle to vehicle (V2V) communication and the vehicle to infrastructure (V2I) communication that are efficient communications. US Federal has given a 75MHz of DSRC spectrum at 5.9GHz for V2V and V2I communications. The applications of the VANETs can be classified into two categories: 1) *Safety applications:* Emergency messages, accident related alerts etc.
2) *Non Safety applications:* these include the downloading of the traffic related information, downloading video or audio files, accessing the internet for various other personal purposes.

The main challenges that occur in VANETs are high mobility of the nodes, dynamic topology, and frequent link breakage so serving to the vehicle before it goes out of the coverage of the RSU is very important. The frequency range is defined from 5.865 to 5.925GHz. On the basis of the standard draft of IEEE 802.11p and 1609 standard family, VANETS use the Dedicated Short Range Communication (DSRC) technique [18] for sending safety information for safety driving. VANETs are not purely mobile adhoc network, there are certain equipments that are equipped inside the vehicles for the communication with the other vehicles and the Road Side Units (RSUs) which are stationary at the road side and are connected to other RSUs or the wired or wireless internet connections that is called as the OnBoard Units (OBUs). The OBUs has a radio interface that is used to connect to the other OBUs and the RSUs and also has wired or wireless –interfaces to which an application unit can be attached. Through DSRC spectrum a new standard is being introduced that is known as the 802.11p [19] that extends the IEEE 802.11 standard for high-speed network communication and 802.11p covers the data link layer and the physical layer of the Wireless Access in Vehicular Environment (WAVE) protocol. The IEEE 1609 family of standards covers the other five layers of the WAVE. The IEEE 802.11p/WAVE has set some physical and MAC (Medium Access Control) layer specifications for communications in VANETs. They apply the technique of multichannel coordination scheme where each vehicle switch periodically to two channels, the Control Channel (CCH) which is for the transfer of safety related messages and Service Channel (SCH) for the non safety messages. According to UTC, the channel is divided into synchronization interval of 100ms, 50ms of CCH and 50ms of SCH. There is also a 4ms of guard interval for radio switching delay. The whole bandwidth is being divided into seven channels of the above frequency range, the control channel(CCH) that transmits the safety related information contains the channel 178 of frequency ranging from 5.885 to 5.895 and remaining six channels are for the service channel(SCH) for applications that are the non-safety applications like videos, road maps etc. The IEEE 1609.4 is being considered for default multichannel MAC standard for the wireless radio operation and interleaving between CCH and SCH. A globally synchronized channel scheme co-ordination is based on Coordinated Universal Time (UTC). The safety applications of VANETs include the applications such as collision avoidance warning, lane changing assistant, further road hazard notification etc. These applications mentioned above usually demand a one hop communication due to the heavy traffic on the road but broadcasting safety information could to be favorable to all the vehicles that are around the sender because safety messages are to be broadcasted for emergency notifying purposes to all the vehicles Besides of safety and non-safety information there are also other message that are being periodically transmitted over CCH that are: 1. Short status messages (beacons) 2. WAVE basic service set (WBSS) 3. Advertisement Messages (WSAs).

Beacons are being broadcasted by a vehicle to keep informed to the neighbor vehicles about their position and speed and other kinematic information. This is useful for collision avoidance etc., the typical beacon generation rates are in the range 5 to 10 Hz. The WSAs are being sent to advertise the WBSS that provides the connectivity of non-safety services during the SCH interval. These all are being very important and beneficial to all vehicles in a given neighborhood, so they are transmitted as one hop broadcast by each sending node. On the basis of IEEE 802.11p, the vehicular nodes are allowed to transmit the packets only if the channel is being idle and it should be idle for the time duration that is equal to Arbitrary Inter frame Space (AIFS) seconds otherwise it waits for the channel to become free and randomly selects a back off value from a set of integers called as Contention Window (W).

II. LITERATURE REVIEW

In this paper [1] they explained that VANET is a special kind of MANET and it can be categorized into two parts i.e. Vehicle-to- vehicle network or vehicle-to-infrastructure. VANET has some unique properties like high node mobility and rapid changing topology. But still there are some disadvantages in this network. Many researchers have proposed MAC protocol to improve the performance of the network.

In this paper, a survey of MAC protocols for VANET has been provided and classified existing MAC Protocol into three major categories of time-based, dedicated short range communication and directional antenna based. In addition to this they have discussed for their characteristics and their future scope.

Wang et. al. [2] proposes a VCI Multichannel MAC for improving the performance of IEEE 802.11 and 1609 standard and has obtained an optimum CCH interval by conducting chain and markov process and also this paper has concluded a VCI MAC scheme that has provided us an efficient channel utilization while transmitting the large packets that are the service packets and has also provided the higher throughput. In related works, some authors in [20] proposed a vehicular mesh (VMESH) MAC protocols that implies a beaconing distributed scheme to improve utilization of the channel in service channel (SCH). In our VCI MAC, the timing synchronization UTC [21] mechanism is being received by IEEE 1609.4. Here, a multichannel co-ordination scheme is being used where CCH and SCH intervals are also further subdivided for more optimize transferring of packets of information. WAVE nodes not only transmit safety information and a WSA packet on CCH but perform safety measurement. The control channel (CCH) is further divided into safety interval and WSA Interval. The VCI scheme is being provided to adjust the ratio between the CCH and SCH interval which is observed to be fixed but is not possible due to the dynamically changing vehicular traffic.

The Roadside unit broadcasts the VCI packet to all the nodes that contains the length of the CCH interval, it broadcasts it twice where there is more traffic. By this congested situation the VCI packet cannot be heard by many nodes so a WSA packet that is the WAVE service announcement packet is being broadcasted which is being filled by the nodes which wants the service and others are set by 0, they can send acknowledge to respond to WSA packet. The field of WSA is being for latest CCH interval, the nodes with current synchronization cycle will fill it.

To improve channel utilization of SCH, CCH should be optimized, that is done by that the number of reservations done will be equal to packets transmitted on all SCHs with that RSU (Road Side Unit). By the WSA, RSU will contain the number of nodes that are under is coverage.CCH interval announced by different RSU may be variable but the one with long length should be selected for successful transfer of packets.

If RSU is not there then a node with one hop can act as RSU and can broadcast VCI and WSA packets, the least Basic Service Set ID (BSSID) containing node is mostly selected. For SCH interval, VCI scheme adopts the scheme the WSA packets are being broadcasted containing identities of SCHs to be used and other information , the other nodes can optionally opt for services with an acknowledge (ACK) they will get SCH ID and transmission duration. The nodes sends the RFS(Request for Service) packet, the nodes that wants the service will send RFS packet with ID of service provider and service types, then based on the channel conditions the service provider will accept or reject the request. They will be given if more than one channel is free and he service provider will give channel used in previous data transmission. If request is accepted, service provider sends an ID of SCH to be used by ACK. It selects the SCH interval having least service data packets in next SCH interval. The SCH channel is being opted in an orderly manner.

In [3], the paper explains the impact of the channel on the trust mechanism and uses the *majority wins* approach. At the time of CCH interval vehicles broadcast WSMs that is the WAVE short messages in response to the traffic control event or emergency. As the driver need to know that the messages he gets are true and not fake, there are different mechanism that are being concluded for not broadcasting the irrelevant and unreliable data.

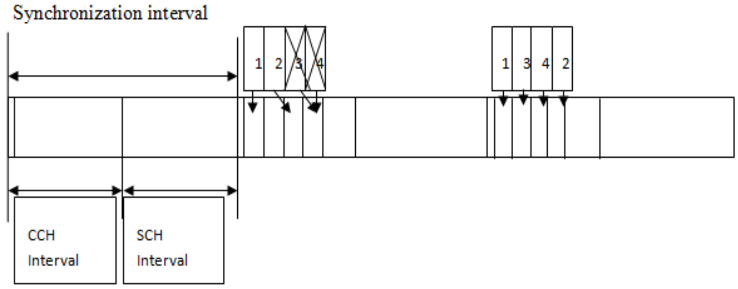

Fig. 1.IEEE 802.11p/WAVE multichannel operation [3]

A number (say X) is being received to avoid the false information about a hazard from the neighbors which are broadcasting the same messages about the hazard. Suppose there are four vehicles as shown in the above figure 1 that send WSMs on CCH. Two of them succeed while other two fails due to collision in first attempt then in second attempt the all other vehicles send WSM successfully. Now, if a vehicle has to wait for four (X=4) messages before conforming about a hazard, there has been a delay of one synchronization interval because of that. This example show that unreliability and unacknowledged broadcasting of the messages and the contention on the MAC could affect the decision delay probability of the packet and hence performance.

Suppose we explain the concept of majority wins by an example, suppose we contain N vehicles which are capable to detect road events (in figure 2 block A) by sensors and cameras then that area is being denoted as detection area and No (No<N/2) is being denoted as intruders and other legitimate areas.

Legitimate users always broadcast same messages about hazard and intruders are considered not be broadcast same message (no cooperation) and other N* are the decision area which makes the decision about the realism. The derivation of the decision delay D of majority wins scheme has to be done that contains X=|N/2| messages for informing the driver from the neighboring vehicles. This scheme depends upon No/N which is the ratio of intruders. By 802.11p MAC specifications a vehicular node is allowed to transmit the packet only if the channel is being found idle for a particular time duration equal to that of Arbitrary Inter Frame Space (AIFS) seconds and if it is not idle it waits for it to be free and randomly selects a number a back off value from a set of integers called as the Contention Window (W), which is then decremented up to 0 the node is allowed to access channel. In WAVE, application layer is aware of channel switching and at beginning of CCH interval the nodes are ready with their WSMs, and also lifetime of WSMs are being bounded to only one CCH interval and after that they are dropped. The packets are sent to MAC layer only during control channel interval.

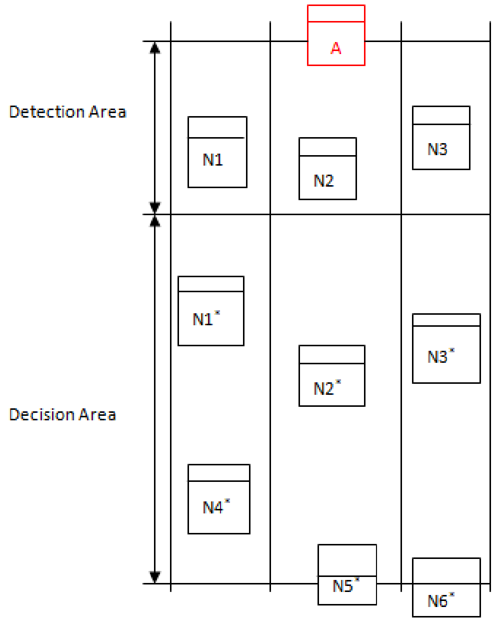

Fig. 2. Detection and Decision areas.[3]

In [4], the paper explains the analytical model of the beacons and the Wave Service Announcement (WSA) by taking into consideration the channel switching. Besides of safety and non-safety information there are also other message that are being transmitted periodically over CCH that are:-

1. Short status messages (beacons)
2. Advertisement Messages (WSAs)
3. WBSS (WAVE basic service set)

Beacons are being broadcasted by a vehicle to keep informed to the neighbor vehicles about their position and speed and other kinematic information. This is useful for collision avoidance etc., the typical beacon generation rates are in the range 5 to 10 Hz. The WSAs are being sent to advertise the WBSS that provides the connectivity of non-safety services during the SCH interval. These all are being very important and beneficial to all vehicles in a given neighborhood. On the basis of IEEE 802.11p, the vehicular nodes are allowed to transmit only when the channel is idle that is for particular time duration that is equal to Arbitrary Inter frame Space (AIFS) seconds otherwise it waits for the channel to become free and randomly selects a back off value from a set of integers called as Contention Window (W) and when the counter decrements to zero the vehicle node is allowed to access the channel.

Each the vehicle node is supposed to have a packet of either a beacon or WSA at beginning of each CCH interval, application layer is supposed of channel switching and packet is sent to MAC layer only at the time of CCH interval and also according MAC the channel is considered as busy at the time of guard interval so all transmissions are delayed at the start of the control channel interval such that the vehicles do not attempt to transmit the packet simultaneously upon the switching. The lifetime of WSA and beacons is bounded to one CCH interval the new beacon is being replaced by new one at the beginning of next interval, the non-transmitted frames are dropped. MAC layer buffer of a vehicular node keep only one frame for CCH interval at a time.

In [5], the author *Hung et. al.* proposes a multihop MAC protocol that is called as the BUFE-MAC for the uplink and downlink communications between the RSUs and the vehicles and thus enhances the bandwidth utilization by using the same bandwidth for the uplink and downlink internet access unlike the cross-layer protocol called CVIA protocol proposed by *Kormaz et. al.* [22].

To reduce the cost and help vehicles to access the data efficiently, an integrated network that combines vehicles using multi hop and the RSU as a gateway between the wired and the wireless connections is being considered in this paper. Because the dedicated short range communications is based on the 802.11 medium access control, the vehicles that are applying the DSRC exchange their data in the medium access. In a normal environment the vehicles that are far away from the connection service get low internet access or are even facing starvation, so a multihop environment of vehicles with not a fully deployment of the RSU, the bandwidth utilization and transmission fairness is an issue. Many number of MAC protocols are being proposed for that.

For enhancing the bandwidth utilization and reducing the packet collision there are some categories that are being explained that are the 1) contention based approach 2) contention free approach 3) integrated approach. In contention based protocols the point of time of transmission is being determined according to the distance between the source vehicle and the destination vehicle and in the contention free protocols the transmissions of the packet can be scheduled in advance. In integrated approach both contention based and contention free mechanism is being used.

Korkmaz et. al,[22] proposed a cross layer protocol that is the controlled vehicular internet access (CVIA) is being proposed for the vehicular internet access for applications of the highway where it is considered that all vehicles are containing the GPS (Global Positioning System) by which everyone is known of the position of each other. The uplinks and downlink internet access are being used for transferring packets to and from the RSUs that are the internet gateways and the uplink and downlink internet access are being are being achieved by connecting to same gateway by multi hop manner with different channels. This protocol states that there will be two vehicles in each segment that will relay the packet to the other segments and acts as routers.

The CVIA and CEPEC approach has explain the multi hop approaches in VANETs. The bandwidth utilization is low in these approaches. It explains that there are six equal sized segments S1,….,S6 that is the service area of the internet gateways are being divided in these six segments each segments contains two vehicles to relay the packets and by connecting to the same gateway that is the IGW1. The uplink and downlink internet access is being achieved by connecting to this same gateway in multi hop manner with different channels and specific time slot is being assigned for parallel transmissions and fairness is being achieved by compulsorily using one-sixth amount of the bandwidth in its active time slot. As there is very low bandwidth utilization in this protocol this paper proposes a MAC protocol for efficient bandwidth utilization by integrating the uplink and downlink transmissions into a single channel and determining an appropriate segment length and also maintaining the fairness.

The basic concept of Bandwidth Utilization and Fairness enhancement- Medium Access Control (BUFE-MAC) is dividing the time into several time slots for the vehicles in proper segment accessing bandwidth. It is being observed that the uplink bandwidth utilization and the downlink bandwidth utilization of the segments that are closer to the same internet gateway are far better than the segments that are far away from the internet gateway. By understanding this issue we have proposed the scheme of BUFE-MAC changes the direction of the downlink packets and thus also the internet gateway from where they will access the internet i.e. now the uplink and downlink IGWs for a same segment are different. Thus, now there no need of dividing the bandwidth into two separate parts for uplink and downlink, the same bandwidth will be used.

The figure 3, above gives an example of the data transmissions that are carried out in BUFE-MAC. The uplink packets are being sent to the IGW1 and the downlink packets are being obtained from the IGW2. Thus when the downlink packets are being received by the vehicles segment 6 the router in it merges its uplink packet in it and passes it to the router in segment 5 thus the router merges its uplink packet s5 with the obtained downlink packet s1-s4 and passes it further thus at the end the segment 1 adds its uplink packet and pass all of the uplink packet to the internet gateway 1 (IGW1).Thus the total number of packets transmitted together is maximal.

There is one more thing that is being explained in this paper that explains the BUFE-MAC algorithm and this algorithm supports two modes: 1) the mesh backbone based mode and 2) the infrastructure mode. The mesh-backbone based mode allows vehicles to transmit the data in a multi hop manner and in the infrastructure mode the vehicles directly communicate with the RSU and exchange data with it. It is usually used when there is a curved rode and segments are not enough to meet them and thus vehicles directly sends request to the gateway and access the internet.

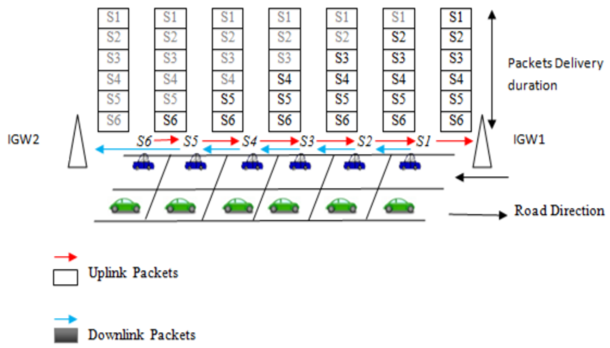

Fig. 3. Data Transmission architecture in BUFE-MAC.[5]

The mesh-backbone based mode of BUFE-MAC is consists of following five phases:

1. Inactive
2. Manager selection
3. Intersegment packet relaying
4. Minislot scheduling
5. Local packet sending

Except for the inactive phase all the vehicles are in active state that are in the remaining for phases. The vehicles in the inactive phase cannot send the packets but can only receive packets. The segment length proposed in BUFE-MAC is $r_{com}/2$, where r is the maximal length that vehicles in neighboring segments can directly communicate. For avoiding the collision of packets at the receivers end the vehicles that are at the r_{com} distance of the receiver cannot transmit the packet. Thus as in [4], figure 3 the vehicles form segment Si are the senders and Segment S_i-1 are the receivers and for avoiding collision the next segment S_k is the segment that can send the packet where k<=i-4.

When the segment changes its state from the inactive phase to manager selection phase where each vehicle exchange their location information and bandwidth requirement the segment chooses a manager vehicle that will relay the packet to the next segment, and then in the intersegment packet relaying phase the manager will relay the packets to the next segment.

In the minislot scheduling phase the remaining time is being divided into slots where manager gives these slots to the vehicles for the transmission schedule according to the requirement of the bandwidth collected in the manager selection phase. And then the vehicles in S_i turns to the phase of local packet sending and transmit their packets to the manager in neighboring segments.

In [6], the author has given four reliability metrics that are the Packet Reception Rate (PRR), Packet Delivery Ratio (PDR) and Successful Packet Delivery Probability (PDP) and its analytical models. The safety applications of VANETs include the applications such as collision avoidance warning, lane changing assistant, road hazard alert notification etc. These applications mentioned above usually demand a one hop communication due to the heavy traffic on the road but broadcasting safety information could to be favorable to all the vehicles that are around the sender because safety messages are to be broadcasted for emergency notifying purposes to all the vehicles. But the broadcasting of the message requires reliability and timely broadcasting in the heavy traffic, the problems that usually comes while broadcasting a message is hidden terminal, the changing topology of vehicles and the issues caused due to the simultaneous transmissions. The basic mechanism for the medium access that is being included in the 802.11p protocols is the Distributed Coordinated Function (DCF). The broadcast procedure of the 802.11 MAC protocol follows the basic medium access protocol of the DCF with the three functions (request to send (RTS)/ clear to send (CTS), retransmission, and acknowledgement) that are being disabled. The hidden terminals that are being mentioned above are the two terminals that are actually outside from the interfering range of each other but share a common set of terminals such that they are in the communication range of both of terminals.

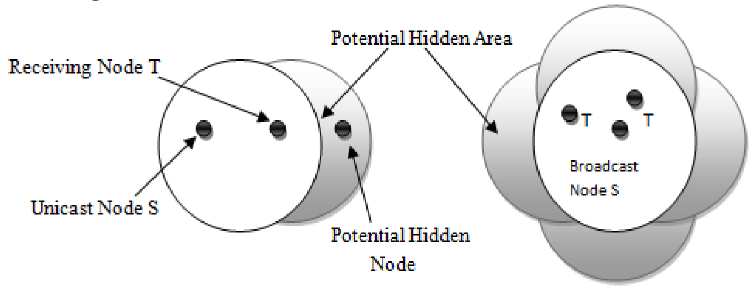

Fig.4. Comparison of hidden terminals between unicast and broadcast unicast (b) broadcast [6]

The figure above shows the hidden terminal concept where the figure (a) is for the unicast communications and the sender id the node S and the receiving node is T. the shaded area is being called as the potential hidden node area. The potential hidden area node for unicast communications can be calculated by calculating the distance between the sender and the receiver. The potential hidden node are in case of the broadcast communication will be greater as there will be need of including all the nodes that are within the transmission range of the sender. In terms of adhoc networks the hidden terminals is a critical issue.

Reliability is the major part when it is concerned with broadcasting the message because the message should be reliably being sent to the nodes for safety purpose. The reliability in the context of the VANET is being defined as the ability of the network that within the specific duration all the intended mobile nodes should receive the broadcast messages. The terms that are being explained in this paper are that are the reliability metrics for one hop transmission in 1 dimensional and the four reliability metrics defined are: Packet Reception Rate (PRR) or Packet Delivery Rate (PDR) that is a function of the of the intended broadcast range, Packet Delivery Probability (PDP) which is being defined as the function of the distances between the sender and the receiver, and the Effective Range (ER). As compared to the existing models for the reliable broadcast in VANETs, the major features that has being mentioned and analytically explained in this paper consists of: 1.That instead of concerning about the multi hop communications this paper proposes a one hop broadcast reliability of the safety applications. 2. New reliability metrics has being identified. 3. Different from the existing PRR and PDR. The PRR and PDR that was explained before are the average metrics among all the receivers that are within the senders' transmission ranges and the new PRR and PDR in this paper are the function of the receivers' distances to the broadcast sender.

Each of the terms PRR, PDR, PDP and ER are being explained as below:

1. PRR (Packer Reception Rate):

PRR is being defined as the percentage of the node that receive the packet from the tagged node that is sender and receiver are among the ones that are in the communication range of the sender.PRR is receiver centric reliability index that evaluates how a packet sent by a sender is being received by the receiver. As explained before the new PRR is different from existing PRR in case that The PRR that are explained before are the average metrics among all the receivers that are within the senders' transmission ranges and the new PRR and PDR in this paper are the function of the receivers' distances to the broadcast sender.

$$PRR(d) = \frac{\text{No. of nodes with distance d receiving a packet from a tagged node}}{\text{Total no. of nodes with distance d from tagged node}}$$

2. PDR (Packet Delivery Ratio):

PDR is being defined as the ratio of the number of packets that are being received by all nodes that are the receivers to the number of packets that are being sent by the tagged node. The PDR is transmitter centric reliability metric that evaluates that how the packets those are being transmitted by the sender is being received by the receivers.

$$PDR(d) = \frac{\text{No. of packets sent by tagged node}}{\text{No. of packets received by all nodes with distance d from tagged node}}$$

3. Successful PDP (Packet Delivery Probability):

Successful PDP is mainly concerned with how an individual node gets the packet that is being sent by tagged node. It is being defined as the probability that a node i with distance d_i from the sender successfully receives the packet from the aged node.

$$P_{spd}(d_i) = \frac{\text{No. of Packets received successfully by node i}}{\text{Total no. of packets transmitted by node i}}$$

4. ER (Effective Range):

Effective Range that is being denoted as ER is the range within which the worst case of QoS metrics is satisfied, and further ER is being defined as the range in case of one-hop message broadcast within which the minimum PDP value is greater than the already defined threshold.

In [7], the author proposes an efficient and reliable protocol called as the VER-MAC protocol where the CCH interval is being utilized during the SCHI interval for transmitting the emergency packet twice for reliable transmission of the emergency packet to successfully notify the driver and also it utilizes the resources of SCH during the CCHI interval efficiently. The control channel is being used to transmit the safety related messages and the service channels are used to transmit he nonsafety packets. The time for accessing the channel is being divided into Synchronization Interval (SI) consisting of the CCH interval (CCHI) and the SCH interval (SCHI). All nodes will tune to the CCH interval during the CCHI to exchange the emergency packets as emergency packets are the important packets that should be sent for notifying the driver about the critical conditions that would be coming further and other WAVE service announcement (WSA) packets and at the time of SCHI channel the nodes will tune to one of the six service channels and thus all service channels are not being utilized. The variable CCH interval that is the VCI multichannel MAC scheme can dynamically adjust the duration of CCHI to improve saturation and the Dedicated Multichannel MAC (DMMAC) states that the both channel can be accessed at once or it is called as the hybrid channel access that provides collision free transmission for safety traffic. The SCH resources are wasted in both of these mechanisms but the SCH resources can be fully utilized by using the extended transmission mode of IEEE 1609 and broadcast reliability of the message can be achieved by retransmission of the emergency messages. The multichannel MAC scheme helps in enhancing the reliability of the safety packets and also the transmissions of the safety packets.

The VER-MAC utilizes the CCH interval at the time of SCHI interval for broadcasting the emergency (EMG) packets and each emergency message is broadcast twice a SI to increase the packet delivery ratio for example if an emergency packet is broadcast at CCHI interval then the copy of the same emergency packet is being sent by the next SCHI interval by delaying the CCHI interval that is delaying by 50ms. On each SCH, the proposed CCHI and SCHI are being divided into M transmission slots and each node send a WSA packet to get a slot, the slot is being called as the Tx_slot. The maximum number of that can be utilized from the six SCHs for the 1609 and the VER-MAC are 6M and 12M respectively. Nodes shift to the SCH interval according to their respected slots. Each node maintains the information of its neighboring nodes using the Neighbor Information List (NIL) and Channel Usage List (CUL).the NIL stores the SCH and TxSlot of neighbors while CUL shows the available Txslots for each neighbor.

In [8], The safety messages should be reliable and timely as it should be reached to the intended receiver with high packet reception rate (99%). The emergency messages are transmitted with higher priority over beacons and beaconing is important as it forms the diverse range of ITS. The channel if not managed could cause congestion as the MAC layer with this high frequency and thus the quality of Service (QoS) would be affected. There should be proper coordination at the MAC layer where there will be high density of vehicles, so there should be a proper solution to this and thus a predictable traffic TDMA that is the time division multiple access which is being preferred over the contention based

MAC mechanism also the Global Positioning Systems (GPS) can be equally preferred as the solution for the efficient exchange of the beacons.

In this paper the author proposes a scalable MAC protocol that is based on the TDMA configuration i.e. Congestion-Controlled-Coordinator based MAC (CCC-MAC) that has been designed to address the dissemination of the emergency messages, safety critical messages in VANETs. The highway is being divided into virtual segments where each segment contains a local coordinator that assigns time slots to the vehicles for the beacon transmissions. In this protocol they have tried to reduce the beacon transmission which is obtained using high 802.11p data rates. The TDMA configuration is designed to counteract the interference effects induced by high data rates. This paper proposes a collision free channel access by beacon scheduling that controls the congestion by using multiple DSRC data rates. A mechanism is proposed to efficiently sent the emergency messages and also proposes a inter segment slot transfer for efficient bandwidth utilization. The related work states that the basic MAC method of 802.11p is same as that of that of the distributed coordinated function of IEEE 802.11 which also uses the CSMA/CA mechanism. In CSMA/CA a node transmits the packet when channel is idle or waits for a random backoff value if busy. The MAC is being extended to the EDCA mechanism that is the Enhanced Distributed Channel Access which assigns service differentiation parameters for the transmissions of the highly emergency messages but also contains some constraints in case of large number of vehicles. The delay of the messages and non reliability of the messages is the major issue by concerning all the mechanisms that are being stated till now. By the studies it is being stated that CSMA/CA is inefficient for real time communications. Thus for avoiding the collision and a conflict free MAC the TDMA mechanism and the space division multiple access/ Location division multiple access are being proposed in the literature. In SDMA/LDMA the road is being divided into cells where each cell consists of at most one vehicle and medium access is being provided based on the their instantaneous geographic location using predefined cell to slot mapping rules but the drawback of this is that it lacks in efficient bandwidth utilization. A self organizing TDMA is also being proposed where each vehicle is being assigned slots based on its position that is being checked by coordinating with the neighbor. Since it does not possess knowledge about the vehicles that are beyond their communication range the hidden terminal problem comes into picture in its performance.

The motivations and the design objectives that are explained in this paper are as follows:

A. Congestion scenario in VANET

Recently the congestion problems in the VANETs have been experienced by which the safety messages are not being sent properly to the receivers, as the bandwidth is being utilized fast when greater number of vehicles transmits packets at higher frequency say of 10 Hz thus the beacons that contains the information of the surrounding environment are being lost due to the collisions .Thus the objective of this paper is to design a medium access scheme that sufficient bandwidth is being allocated to the emergency messages and beacons.

B. Congestion Control Methodologies

The recent years has proposed many congestion control approaches which contains of reducing the beacon load. The congestion control mechanism relies on three key specifications based on the transmissions of the beacons that are the frequency, transmission powers and the transmission duration

C. Reducing Transmission Duration

Increasing the data rate of the beacon can reduce the transmission duration of the beacons which also reduces the beacon load on the channel.

D. Fairness in Data Rate Assignment

6 Mb/s is the lowest data rate that is being provided for transmitting the beacons. However, the higher data rates contains high noisy channel they are being used when the load is higher than 6Mb/s.

E. MAC for Multiple Data Rate Transmission

In this on the basis of the predictable traffic in VANETs the time slot based protocol is being proposed in which the road is being divided into number of segments that are of equal width and are allocated slots which contains two periods, one for the small data rate and other for the higher data rates. This transmission period consists of the time slots where each node can send its emergency message or beacons or event driven messages and due to the different data rates taken by different nodes are different the duration of the slot varies. Each segment is defined with a unique identifier.

F. Centralized Scheduling

The time slot assignment in a particular segment is being decided by two approaches that is the centralized and distributed. In distributed approach the vehicles itself chooses the time slot and the centralized approach in which the node near to the centre of the segment is being appointed as the local coordinator which assigns time slots and data rates to the other vehicles based on the load in the segments and then broadcasts the scheduling information.

In [9], the authors has has proposed two markov chain models for the ACs with different priorities for analyzing the performance and reliability of the safety-critical data broadcasting in CCH. The EDCA has allowed four access categories (ACs) for the applications in station according to how critical the safety messages are, they are as follows: 1) AC[0]: This has the highest priority which contains the emergency messages such as the accidents, missing traffic sign, about the roads and the information related to the vehicle like speed limit of the vehicles.

2) AC[1]: This contains the priority that is higher than AC[2] but less priority than AC[1] which contains the messages about the information of the speed that is broadcasted by the vehicles.
3) AC[2]: This has higher priority than the AC[3] but has less priority than AC[1] which contains the information that is sent by the vehicles for help by no risk of harming but asking for help if the petrol is over. 4) AC[3] : This contains the least priority that contains information about establishing a new nonsafety related connection which switching on to the SCH. But all the messages are broadcasted through the CCH.

This paper is based on the analysis of the 802.11p protocol that is related the safety messages broadcast on the CCH that is based on the EDCA in a VANET environment. The primary technique that is being used for the 802.11 MAC is the distributed coordinated function (DCF) that is being used by the most previous works on VANETs broadcast performance analysis. There are also studies done on the VANET broadcast based on the 802.11 EDCA for improving the reliability and performance of the 802.11 EDCA broadcast for safety applications. Pereira and Shahnasser has evaluated that how the various transport elements influenced the reliability of EDCA broadcast protocol based on the simulations. Some work s studies on introducing multiple ACs with distinct parameters including the minimum and maximum contention window. Some works also included the 3-D markov chains of the 802.11 EDCA including both parameters of the arbitration interframe space (AIFS) and the contention window but a very few works are being done on the performance and reliability of the 802.11 EDCA broadcast.

A. *VANET Model Description*: The authors have considered a bidirectional highway with one lane for each direction. The maximum communication distance that is defined in 802.11p is 1km and neglecting the side lane vehicles and this highway scenario is being modeled as 1-D VANET model. The node in this paper means one vehicle.

The communications range(R) is the distance where we can successfully send or receive the packet which is dependent on the transmission power and channel fading. The L_{cs} is the carrier sensing distance where signal is being detected and is a key parameter to the carrier sensing multiple access CSMA/CA. The interference range (L_{int}) is being defined as the range that is greater than the communication range but is smaller than the carrier sensing range, as the signal is not reaching the receiving threshold it may have impacts on the normal receiving. The blue nodes that are seen in the diagram are the hidden terminals that are not in the communication range but can still interfere in the receiving range of the vehicles that are receiving packets from the tagged node.

B. Some assumptions that are considered in this paper are that:

1. The vehicles in the 1-D highway environment are exponentially distributed.
2. The safety critical messages are very small that they can fit into a single packet.
3. It is considered that the transmission link is not broken for one transmission and that the mobility of the vehicles stays stationary atleast for one transmission of the packet.
4. The 802.11 EDCS provides each of the AC with a MAC queue entity to access the channel.

The Differentiation Parameters in EDCA: The EDCA allows the four access categories (ACs) for the applications with different priorities and also with different level of their criticalities where the AC[3] is with the lowest priority and the AC[0] is with the highest priority and these different ACs are being identified by the contention window (CW), the arbitrary interframe space (AIFS) and the transmission opportunity (TXOP) which are different parameters for accessing the channels.

EDCA Backoff Procedure and Virtual Collision Handling: The EDCA is the extension of the 802.11 DCF. The access categories (ACs) behaves as an enhanced DCF with the parameters of the contention window, AIFS, backoff instance and MAC queue entity. The ACs form comes from the above five layers to the MAC layer where they queue up for the transmission. The backoff instances in a node can be considered as independent of each other. Now when the ACs arrive they check that whether the channel is being idle for a particular time equal to the AIFS, if not then they wait for the particular time until the channel is idle for the time period equal to the AIFS. The ACs takes a random value from its CW and starts a backoff procedure. The receiver sends an ACK packet to the sender when the packet is received by the receiver. If the sender does not receives the ACK packet in the predefined ACK timeout period then another backoff procedure containing the double CW is invoked for the transmission of the packet. After each unsuccessful transmission the CW will be doubled upto it reaches the limit of the CW_{max} or the transmission number is upto the retry limit. Now the virtual collision can be solved by taking into account the priorities of the ACs which occurs when two or more backoff instances are trying to access the channel at the same time slot. In this case, the frames that are having the higher priority can initiate the transmission and the other frames enters the another backoff instance with double CW upto the limit of the CW_{max} and the transmission limit reaches upto the retry limit. In the broadcast case the packets are being broadcasted by the sender where there is no matter of the ACK packet and the AC[0] is free with the virtual collision.Thus for that a 2-D markov chain model is designed.

In [10], the author proposes VeMAC, a multichannel novel TDMA MAC protocol that is designed for VANETs. The MAC provides efficient broadcast services. There are many MAC protocols that are being proposed that are based on the IEEE 802.11 standard that consists of time division multiple access (TDMA), space division multiple access (SDMA) and the code division multiple access (CDMA). The SDMA contains of mainly three parts: *discretization scheme* which divides the roads into equal size of areas that are called as the cells. *Mapping function* distributes the time slots to the different cells and *assignment rule* assigns the particular time slot to every vehicle where it can access the channel. The CDMA is being mainly used for the robustness against the noise that is interfering in the communication. The IEEE 802.11p standard has recently developed the MAC protocol based on the legacy of the IEEE 802.11 standard for broadcasting services. It is widely used but do not provide efficient service as the broadcast services do not contains the RTS/CTS or the acknowledgement received from the vehicles which have received the packet. The other limitation is that according to the enhanced distributed channel access (EDCA) scheme defined in the IEEE 802.11 standard the higher priority messages are assigned to the higher priority access categories (ACs) and also the channel allows the higher priority ACs to transmit the message with very small delay which causes the collision when the two nodes want to send the data with same communication range.. The ADHOC MAC protocol operates in a time slotted structure where the time slots are grouped into virtual frames. Each sends the status of the time slots previously accessed. ADHOC MAC also provides multihop broadcast service which is used to relay the messages and in ADHOC MAC each node is being is being guaranteed to access the channel atleast once. But there are some limitations that sometimes due to the high mobility of the vehicles the throughput reduces to upto 30% and the ADHOC MAC is known as the protocol for single channel and not suitable for the seven DSRC channel.

The VeMAC protocol provides a reliable one hop broadcast service at the control channel and also the multihop broadcasts service which avoids the hidden terminal problem. It assigns disjoint sets to the vehicles moving in opposite directions and also to the RSUs which decreases the collision at the control channel which is caused by the node mobility. The VeMAC protocol also provides considerably high throughput on the control channel which is a limitation of the ADHOC MAC protocol.

The VANET model that is used in this paper consists of set of vehicles that are moving in the opposite directions and the RSUs. The vehicles moving in the left direction are known to be moving from the north/south towards the west and the vehicles moving in the right direction are known to be going towards east. There is one control channel known as c_o and the other service channels from c_1 to c_m where m=0 to M. The *provider* announces for the service at the control channel c_o for accessing the service the *user* is the user node that needs the service. Each user node has two transceivers: Transceiver1 is used for accessing the control channel and Transceiver2 can be tuned to one of the service channels. All the seven channels are symmetric in nature that suppose that there are two nodes x and y, and the node x is in the communication range of y if and only if node y is in the communication range of x. Each packet that is transmitted on the channel contains a MAC address that is the ID which is sent by the packet when there is transmission of the packet on the control channel $c_{o,}$ if the ID is already used by the other node it is changed. The time slots are being partitioned into frames and each frame contains fixed duration of time slots. The time slots of the service channels c_m are being denoted by s_m where m=0 to M. The frames in the control channel are being divided into three parts *L*, *F* and *R*. The F frame is associated with the RSU and the L and R are the sets that are for the vehicles moving in the left and the right directions.

Each node including the Road side unit is being equipped with the global positioning system (GPS) which can accurately determine its position with the help of GPS. The current position of the node is also being included inside the header while sending the packet on the control channel c_o and the synchronization of the vehicles is being done by the 1PPS signal provided by the GPS receiver. The rising edge of 1PPS is being aligned with the start of every GPS second and consequently it is used as the common time reference among the nodes. The channels are slot synchronized and each second on the channel contains equal number of frames as it is shown in the figure 9.

In the VeMAC protocol each node acquires a specific time slot in a frame in the channel c_o and when the channel is acquired by the node it uses the same time slot in each frame every time it transmits the packets unless a collision occurs. Each packet that is sent by the node in the control channel is being divided into four parts that is the Header, announcement of services (AnS), acceptance of services (AcS), and high priority short applications as shown in the figure 5 that is shown below.

Header	AnS	AcS	High priority short applications

Fig. 5. Format of each packet transmitted on channel c_o. [10]

Even if there is no data to send to send when there is the time slot of the particular node the packet should be sent by the node because the rest of the information that is Header, AnS and AcS are of importance as the other nodes to decide which slot should they take for the transmission on the control channel and service channel. There are two types of collisions that occur at the control channel c_o that is the access collision and the merging collision. In the access collision two nodes tries to access the same time slot for transmission and the merging collision is that the two or more nodes that are trying to acquire the same time slot become members of the same two hop set (THS) due to the node mobility.

The main difference between the two is that access collisions occurs when two nodes are trying to acquire the same time slot and the in merging slot the two nodes have already acquired the time slot. In VANETs, the merging collisions usually occur when the two vehicles are moving in the opposite direction. For example the vehicle x moves to the THS2 and is using the same time slot as z then the collision will occur at y. when the merging collision is being detected both node releases their respective time slot and tries to acquire the new one which may generate more access collisions. The multihop broadcast that is described in the ADHOC MAC can be used by the VeMAC directly. The conclusion of this paper is that this paper proposes VeMAC, a TDMA MAC protocol that is based on the ad hoc MAC. Each node is being ensured to access the control channel once per frame and thus the nodes have equal opportunities to access the services that are provided on the service channels. VeMAC provides one hop broadcast service which is considered as crucial for high priority safety applications on the control channel and also an efficient multihop broadcast. VeMAC provides smaller rate of transmission collision as compared to that of the ADHOC MAC.

In [11], In this paper a Cooperative ADHOC MAC (CAH-MAC) has been proposed by the authors that is basically focusing on the MAC layer and is based on the distributed TDMA based MAC protocol unlike the existing cooperation networks of the 802.11 based networks and/or the infrastructure networks. The distributed TDMA based MAC approaches such as the ADHOC MAC and the VeMAC are explained for the transmission of the packets but also leads to the wastage of the time slots. The wastage of the time slots occurs due to the lack of enough neighboring nodes to use the time slots so in case of transmission failure the nodes the source has to wait for the next frame to achieve the time slot.

Various techniques are implemented in it but the one is the cooperative transmission where upon the failure of the direct transmission from the source to destination (s-d). At the time of the broadcast of the wireless communications the packets can be overheard by the neighboring nodes that are sent form the source to the destination and this overhearing of the packets can be used to relay the packets from the source to the destination on the failure of the direct transmission of the packet from source to destination. The nodes that relay the message are known as the helper nodes. The helper node uses the idle time slots for relaying the packets from the source to the destination and as the helper node uses the unreserved timeslots for the transmission the CAH-MAC protocol increases the throughput of the network. Various cooperative schemes are being defined such as the CC-MAC scheme that has been defined to reduce the transmission bottleneck congestion near the access points and increase the throughput by allowing the concurrent transmission of the packets. In most of the cooperative based transmission the helper nodes are forced to perform the relaying operation over its ongoing transmission of the packets to the other nodes.

Some assumptions are taken first before explaining the actual scenario of the CAH-MAC, the network topology is considered as the vehicles are in multilane and are the mobility of the vehicles is relative to each other that means they are stationary with respect to each other and has a transmission range r. The nodes which are at a transmission range of the sender can successfully receive the packet with probability p. the smaller the probability the less chance of receiving the packet. Each of the vehicles maintains its one hop and two hop neighbors list to know its neighbors. The one hop set and two hop set are called as OHS and THS respectively. In this cluster of vehicles they can transmit the packet. Accessing the channel is same as that explained in the ADHOC MAC and [10] VeMAC. The channel is divided into frames and the frames are further divided into timeslots which are hen given to the vehicles for the successful transmission of the packets. Each vehicle is equipped with the Global positioning system (GPS) receiver and the 1 pulse per second that the GPS receiver gets can be used for the synchronization. The nodes support different types of communications such as broadcast, unicast and multicast and P2P but, in the CAH-MAC the nodes supports P2P mode of communication. The cluster of the nodes is formed of the two hop neighbors and one node can be a part of more than one cluster. He formation of the two hop set (THS) stops when more than one node uses the simultaneously the same time slot within the same interference range and thus reduces the hidden problem. The channel is accessed by the node when the node listens for channel over F consecutive time slots.

The actual operation of the CAH-MAC is explained further, each node transmits a packet in its own slot that consists of the frame information, cooperation header, packet header, payload data, and cyclic redundancy check. The packet header, payload data and cyclic redundancy check are same that are explained in the in the ADHOC MAC and VeMAC. The frame information contains the collection of the ID fields (IDFs) and the number of ID fields is equal to the F that is number of time slots per frame. The FI field consists of the ID that is shorter than the MAC address and can be used to minimize the load MAC. The Destination D upon receiving a packet form S in the time slot s knows that the s^{th} time slot is of the node S and thus puts the ID of the S in the s^{th} time slot of its FI. Thus each node makes its neighbor table. If there is no signal in a time slot then the nodes concludes that it is unreserved timeslot and is thus used for retransmission of the packets at the time of packet failure. The cooperation always occurs at a one hop or two hop neighbors of the source and the destination. When the node once decides to cooperate it transmits the decision through the cooperation header in its packet, the information that is contained in the cooperation header is the intention of the node to cooperate, the index of the time slot of the source at the time when the failure occurred and the index, the index of the unreserved selected time slot in which the packet will be retransmitted from the helper destination.

III. TABLE

Serial No.	Title	Proposed Work	Results/Improvements
1.	Survey of MAC Protocols for Vehicular Ad Hoc Networks	In this paper, they have introduced the advantages and disadvantages of existing vanet mac protocols along with the comparison of their objectives, design approaches and requirements.	Resolving the problem of short messages, collision and contention of nodes in future scope
2.	An IEEE 802.11p-Based Multichannel MAC Scheme With Channel Coordination for Vehicular Ad Hoc Networks	This paper proposes a VCI Multichannel MAC to help IEEE 1609 for delivering reliable packets and also for maximal throughput. Here, a multichannel co-ordination scheme is being used where CCH and SCH intervals are also further subdivided for more optimize transferring of packets of information.	This paper has proposed a VCI multichannel MAC Scheme that is able to provide efficient channel utilization with higher saturation throughput and low service delay when transmitting large service packets and improved the performance of IEEE 802.11 and 1609 standard.
3.	Trustworthy Broadcasting in IEEE	This paper proposes a mechanism about the trustworthy information that is being	A trustworthy broadcasting of the information that will occur further

	802.11p/WAVE Vehicular Networks: Delay Analysis	sent by the vehicles to make them aware of the hazard that is approaching further by majority wins approach.	by majority wins approach
4.	Modeling Broadcasting in IEEE 802.11p/WAVE vehicular Networks	This paper explains that that based on IEE 802.11p MAC specifications a vehicular node is allowed to transmit only if it detects channel idle otherwise it selects a backoff value taken from the range of integers called contention window.	The IEEE 802.11p MAC layer broadcasting specifications for transmitting the information.
5.	BUFE-MAC: A Protocol with Bandwidth Utilization and Fairness Enhancements for Mesh-Backbone-Based VANETs.	This paper proposes a concept of Bandwidth Utilization and Fairness enhancement- Medium Access Control (BUFE-MAC) is dividing the time into several time slots for the vehicles in proper segment accessing bandwidth and integrating uplink and downlink internet access aiming at taking into account both bandwidth utilization and fairness.	This paper thus concludes a multihop MAC protocol that is called as the BUFE-MAC for the uplink and downlink communications between the RSUs and the vehicles and thus enhances the bandwidth utilization by using the same bandwidth for the uplink and downlink internet access.
6.	Reliability Analysis of One-Hop Safety-Critical Broadcast Services in VANETs	This paper proposes on the one-hop reliability of broadcast which is important for VANET safety critical applications and new reliability metrics are defined like PRR, PDR, ER and PDP to show how different nodes receive the broadcast message differently.	This paper has defined four important reliability metrics for one-hop safety message in VANETS i.e. PRR, PDP and PDR and ERs and an analytical model to evaluate these reliability metrics. This also provides complete overview of the DSRC broadcast for safety messages.
7.	An Efficient and Reliable MAC in VANETs	This paper proposes an efficient and reliable protocol called as the VER-MAC protocol where the CCH interval is being utilized during the SCHI interval for transmitting the emergency packet twice for reliable transmission of the emergency packet to successfully notify the driver and also it utilizes the resources of SCH during the CCHI interval efficiently.	This paper proposed the VER-MAC protocol which allows nodes to broadcast the emergency messages during SCHI and to exchange service packets during the CCHI.
8.	Congestion-Controlled-Coordinator-Based MAC for Safety-Critical Message Transmission in VANETs	This paper proposes a scalable MAC protocol that is based on the TDMA configuration i.e. congestion-controlled based MAC (CCC-MAC) that has been designed to address the dissemination of the emergency messages, safety critical messages in VANETS. The road is divided into number of segments and assigning a fixed transmission period to each segment in beacon interval and then vehicles are individually provided timeslots for transferring messages.	This paper has introduced a MAC protocol i.e. the CCC-MAC protocol which addresses the efficient and reliable safety critical messages in VANETs.
9.	Performance and Reliability Analysis of IEEE 802.11p Safety Communication in a Highway Environment	This paper focuses on the analysis of the 802.11p safety related broadcast messages on the control channel CCH based on the enhanced distributed channel access (EDCA) in VANET environment which is based on the four access categories ACs for applications based on their criticalities.	This paper concludes that it has proposed two markov chain models for the ACs with different priorities for analyzing the performance and reliability of the safety-critical data broadcasting in CCH.
10.	VeMAC: A TDMA-Based MAC Protocol For Reliable Broadcast in VANETs	This paper proposes VeMAC, a multichannel novel TDMA MAC protocol that is designed for VANETs that is based on the previously explained ADHOC MAC protocol. The VeMAC protocol provides a reliable one hop broadcast	The conclusion of this paper is that this paper proposes VeMAC, a TDMA MAC protocol that is based on the ADHOC MAC. Each node is being ensured to access the control channel once per frame and

		service at the control channel and also the multihop broadcasts service which avoids the hidden terminal problem.	thus the nodes have equal opportunities to access the services that are provided on the service channels. On control channel VeMAC provides one hop broadcast service which is crucial for high priority safety applications and also an efficient multihop broadcast.
11.	CAH-MAC: Cooperative ADHOC MAC for Vehicular Networks	In this paper a cooperative ADHOC MAC (CAH-MAC) has been proposed that is basically focusing on the MAC layer and is based on the distributed TDMA based MAC protocol where nodes uses an unreserved time slot for retransmission of packets at the time of failure.	In this paper a cooperative ADHOC MAC (CAH-MAC) protocol is proposed where at the time of the failure of the transmission of packet from s-d the neighboring node is used to relay the packet to the destination during an unreserved time slot for retransmission of packets which increases the throughput.

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