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EVALUATION OF MAC IN VEHICULAR NETWORKS

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ABSTRACT

Vehicular Ad hoc Network (VANET), a subclass of Mobile Ad hoc Network (MANET), is an important one for the intelligent transportation system (ITS).VANET, used to provide communication among vehicles and between vehicles to RSU. These networks have the potential to increase safety and provide many services to drivers and the passengers. VANET has the name as network on the wheel (NOW). Medium Access Control (MAC) is designed to send information from source to destination .We use VER-MAC to send data with reliability and energy efficiency. VER-MAC and IEEE 802.11p are the two standards used in VANETs. In this paper we compare the performance of VER-MAC and IEEE 802.11p standards in terms of two factors i.e. Packet Delivery Ratio (PDR) and the delay of emergency packets. The performance is mainly analyzed using ns-2 simulator.

Keywords: VANET, MAC, MANET, IEEE 802.11p, VER-MAC.

1. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are a special type of Mobile Ad hoc Networks; where vehicles are simulated as mobile nodes.VANET integrates on multiple Ad-hoc Networking technologies such as, Bluetooth, IRA and ZigBee for easy, accurate, effective and simple communication between vehicles on dynamic mobility. VANET helps in defining safety measures in vehicles, streaming communication between vehicles. Vehicular Ad-hoc Networks are expected to implement a variety of wireless technologies such as Dedicated Short Range Communications which is a type of Wi-Fi. Vehicular Ad-hoc Networks can be viewed as component of the Intelligent Transportation Systems (ITS).A Vehicular Ad-Hoc Network or VANET is a technology that uses moving cars as nodes in a network to create a mobile network. VANET turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and, in turn, create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a mobile internet is created. It is estimated that the first system that will integrate this technology are police and fire vehicles to communicate with each other for safety purposes. Most of the concerns of interest to MANETS are of interest in VANETs but the details differ. Rather than moving at random, vehicles tend to move in an organized fashion. The interactions with roadside equipment can likewise be characterized fairly accurately. And finally, most vehicles are restricted in their range of motion, for example by being constraint Vehicle Infrastructure Integration. Virtual Channel Identifier (VCI) is an initiative fostering research and applications development for a series of technologies directly linking road vehicles to their physical surroundings, first and foremost in order to improve road safety. The technology draws on several disciplines, including transport engineering, electrical engineering, automotive, and computer science. VCI specifically covers road transport although similar technologies are in place or under development for other modes of transport. Planes, for example, use ground-based beacons for automated guidance, allowing the autopilot to fly the plane without human intervention. In highway engineering, improving the safety of a roadway can enhance overall efficiency. VCI targets improvements in both safety and efficiency. Vehicle infrastructure integration is that branch of engineering, which deals with the study and application of a series of techniques directly linking road vehicles to their physical surroundings in order to improve road safety. Current active safety technology relies on vehicle-based radar and vision systems. For example, this technology can reduce rear-end collisions by tracking obstructions in front or behind the vehicle, automatically applying brakes when needed. This technology is somewhat limited in that it senses only the distance and speed of vehicles within the direct line of sight. It is almost completely ineffective for angled and left-turn collisions. It may even cause a motorist to lose control of the vehicle in the event of an impending head-on collision. The rear-end collisions covered by today's technology are typically less severe than angle, left-turn, or head-on collisions. Existing technology is therefore inadequate for the overall needs of the roadway system.

This paper is organised in 7 sections.In section 2 we discuss about VANET characteristics, challenges and the related work.Section 3 highlights some of the standards for wireless access in VANET (DSRC) and about system model.Chapter 4 describes about module description, section 5 provides the algorithm.The paper closes with a conclusion in section 7.

Abbreviations

GPS	Global Positioning System
MAC	Medium Access Control
LLC	Logical Link Control

URL	Uniform Resource Location
ITS	Intelligent Transportation System
PHY	Physical
CCHI	Control Channel Interval
SCHI	Service Channel Interval
QOS	Quality of Service
VCI	Virtual Channel Identifier
ABF	Adaptive Broadcast Frame
EMG	Emergency
NIL	Neighbor Information List
RES	Reservation
CRP	Contention-based Reservation Period

2. RELATED WORK

Many advanced wireless technologies are being applied to transport systems to make them safe, intelligent, and efficient. In particular, the Vehicular ad hoc network (VANET) focuses on vehicle to vehicle (V2V) communication and vehicle to infrastructure (V2I) communication and makes it possible to provide a variety of safety applications (such as collision warning and traffic coordination) and non-safety applications(such as Internet access and multi-media data transfer between vehicles).The MAC protocol for VANET is critical to provide efficient and reliable medium access and meanwhile is difficult to design due to fast topology changes, high node mobility and different Quality of Service (QoS) requirements—safety applications require high reliability and bounded delay while non-safety applications are throughput sensitive. Dedicated multi-channel MAC protocol, called DMMAC, for VANET is explained in [4]. DMMAC is based on a hybrid channel access mechanism exploiting both the advantages of TDMA and CSMA/CA. The essential part of DMMAC is a mechanism named adaptive broadcasting. Bounded transmissions for safety messages, and it enhances the adaptability of the MAC protocol to different traffic density conditions. These two issues have not been well addressed in most of the existing multi-channel MAC designs. In DMMAC, all vehicles are equipped with a single half-duplex radio transceiver. This is not just a cost concern: multiple radios implemented with current hardware may suffer from too much cross-channel interference. The overall architecture of DMMAC. The channel coordination scheme is similar to WAVE MAC. The channel access time is equally divided into Sync Intervals, and each Sync Interval consists of a CCH Interval (CCHI) and an SCH Interval (SCHI) of the same length. In DMMAC, the CCHI is further divided into an Adaptive Broadcast Frame (ABF) and a Contention-based Reservation Period (CRP).The ABF consists of time slots, and each time slot is dynamically reserved by an active vehicle (the vehicle whose communication equipment has started working) as its Basic Channel (BCH) for collision-free delivery of the safety message or other control messages. The number of time slots contained in the ABF is called the ABF Length (ABFL). The scope of this standard is the specification of medium access control (MAC) sub layer functions [1] and services that support multi-channel wireless connectivity between IEEE 802.11 Wireless Access in Vehicular Environments (WAVE) devices. To enable effective mechanisms that control the operation of upper layer data transfers across multiple channels, without requiring knowledge of physical layer (PHY) parameters, and describe the multi-channel operation channel routing and switching for different scenarios. Normative text may describe mandatory or optional features. A mandatory feature may have optional as well as mandatory components. For example, a mandatory message may have optional fields. An optional feature may have components that are mandatory if the feature is supported. For dated references, only the edition cited applies. The mechanisms specified in this standard that facilitate Wireless Access in Vehicular Environments (WAVE) [9]operation of at least one physical layer (PHY) over multiple wireless channels, including synchronization. A single radio channel, not a service channel, intended for the exchange of management information, including Wireless Access in Vehicular Environments (WAVE), Service Advertisements, and WAVE Short Messages. Vehicular communications are becoming one of the most important aspects of future vehicle equipment. Vehicular ad hoc networks (VANETs) have been considered to be an important part of the intelligent transportation system (ITS) which is discussed in [3]. Based on the standard draft of IEEE 802.11p [10], VANETs employ the technique of dedicated short-range communication (DSRC) for the enhancement of driving safety, as well as comfort of automotive drivers. The U.S. Federal Communication Commission allocated 75 MHz of the DSRC spectrum at 5.9 GHz to be exclusively used for vehicle-to-vehicle and infrastructure-to-vehicle communications. The overall bandwidth is divided into seven frequency channels.CH178 is the control channel (CCH), which is used as a public channel for safety-relevant applications on the road. The other six channels are service channels (SCHs) for non safety service applications for the comfort of driving. Wireless access in vehicular environments (WAVE) is designed for an ITS on 5.9-GHz frequency with the IEEE 802.11p [11] and IEEE 1609 standard family. The IEEE 802.11p working group is investigating a new physical layer (PHY)/medium access control (MAC) [6] amendment of the 802.11 standard for VANETs. It employs the orthogonal frequency-division multiplexing technique on the PHY, which can provide up to a27-Mb/s data rate with 10-MHz bandwidth and a 300–1000-m communication distance. Transportation systems are designed to transport people from one place to the next as safely and efficiently as possible. Unfortunately, many accidents and fatalities do occur on the road every day. The recent development of the intelligent transportation system (ITS) is an effort toward safe and smooth driving without delay. Wireless communications systems are expected to play a pivotal role in ITS safety-related applications. Dedicated short-range communication (DSRC) radio technology [5] with a 75-MHz bandwidth at the 5.9-GHz [2] band is projected to support low-latency wireless data communications among vehicles and from vehicles to roadside units in North America. DSRC-based communication devices are expected to be installed in future vehicles and to work with sensors in the vehicles to enhance road safety. The draft of the upcoming 802.11p standard, defining specifications of the physical layer and the medium access control (MAC) layer of the vehicular wireless communication networks based on DSRC [4], has been created and distributed for discussions. The DSRC spectrum consists of seven ten-megahertz channels that include one control channel and six service channels. Channel 178 is the control channel, which is generally restricted to safety communications only [2, 3]. The DSRC physical layer uses an orthogonal frequency division multiplex (OFDM) modulation scheme to multiplex data. The DSRC physical layer follows exactly the same frame structure, modulation scheme, and training sequences specified by IEEE 802.11a physical layer. However, DSRC applications require reliable communication between OBEs and from OBE to RSUs when vehicles are moving up to 120 miles/hour and having communication ranges up to 1000 meters. According to the updated version of the DSRC standard, the MAC layer of the DSRC adopts 802.11a layer specification with minor modifications. This is a random access scheme for all associated devices in a cluster based on carrier sense multiple accesses with collision avoidance (CSMA/CA). In the 802.11 MAC protocols, the fundamental mechanism for medium access is the distributed coordination function (DCF). DCF is meant to support an ad hoc network without the need of any infrastructure element such as an access point, but DCF is not able to provide predictable quality of service (QoS). The development of a robust and efficient MAC protocol will be central to the new generation DSRC devices.

a) VANET characteristics and challenges

VANETs are characterized by their special features that distinguish them from MANET. These special characteristics can be summarized as follows:

i. High mobility: VANET nodes are characterized by their high relative speed which makes VANET environment high dynamic.

ii. Predictable and restricted mobility patterns: Unlike the random mobility of MANET, VANET node movements are governed by restricted rules (traffic flow theory rules), which makes them predictable at least on the short run.

iii. Rapid topology changes: VANET nodes are characterized by their high speed. This leads to frequent network topology changes, which introduces high communication overhead for exchanging new topology information.

iv. No power constraints: Each vehicle equipped with a battery that is used as an infinite power supply for all communications and computations tasks.

v. Localization: Vehicles can use the Global Positioning System (GPS) to identify their locations with high accuracy.

vi. Abundant network nodes: Unlike MANETs that are characterized by a small network sizes, VANET network can be very large due to high density of vehicles.

vii. Hard delay constraints: Safety messages are the main goal of VANETs. Therefore, safety messages should be given high priority and must be delivered on time.
The main challenges of the VANETs are:
Frequent neighborhood change due to high mobility.
Increasing channel load (High Density Environment).
Irregular connectivity due to the variation of the received signal power.
Packet loss due to exposed and hidden terminal problems.

3. SYSTEM MODEL

The VER-MAC utilizes the CCH during the SCHI for broadcasting the EMG packet and each periodic/event-driven EMG packet is broadcast twice a SI to increase the packet delivery ratio. If an EMG packet is broadcast in the CCHI (or SCHI), the copy of this EMG packet is scheduled to be broadcast in the upcoming SCHI (or CCHI) by delaying a CCHI (50ms). The purpose of the delay is to avoid the high congestion at the beginning of the CCHI or SCHI. On each SCH, the CCHI and SCHI are divided into M transmission slots which are used for the collision-free service data transmission each node pair performs a WSA handshake to select a TxSlot of a SCH. With six SCHs, the maximum number of TX Slots/SI that can be utilized in the IEEE 1609.4 and the VER-MAC are 6M and 12M, respectively. Nodes maintain the Neighbor Information List (NIL) and Channel Usage List (CUL). The NIL stores the SCH and TxSlot used by the neighbors while the CUL shows the available TX Slots of each SCH. Based on the NIL, a node knows when its neighbor is on the CCH in order to perform a WSA handshake. With six SCHs, the maximum number of TX Slots/SI that can be utilized in the IEEE 1609.4 and the VER-MAC are 6M and 12M, respectively. Nodes only switch to the selected SCH during the selected TX Slot in order to broadcast their own EMG packets and avoid missing the EMG packets on the CCH in another time. Nodes maintain the Neighbor Information List (NIL) and Channel Usage List (CUL). The NIL stores the SCH and TX Slot used by the neighbors while the CUL shows the available TX Slots of each SCH as shown in Figure-1. The time delay for an emergency message to be sent from one vehicle in one cluster and reaches vehicles that are located at distance D from the emergency time. If a vehicle has an emergency message, it will contend for the channel access using

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Access Class (AC) to send this message. Once this message is received by the cluster head, it starts transmitting this emergency message periodically with enough power reach a distance of (Dc), all other cluster members will refrain from using the channel during this time. When the next cluster head receives this emergency message, it will broadcast the message with a range of (Dc) to reach both the next cluster and the originating CHs. Once the originating CH hears its message back from the neighboring CH, it will stop broadcasting the message with high power but continue the broadcasting to all of its members for several times depending on the application or until the emergency situation is cleared. The emergency message will continue to propagate in the direction of interest for a maximum number of hops (M) depending on the application and the emergency situation.

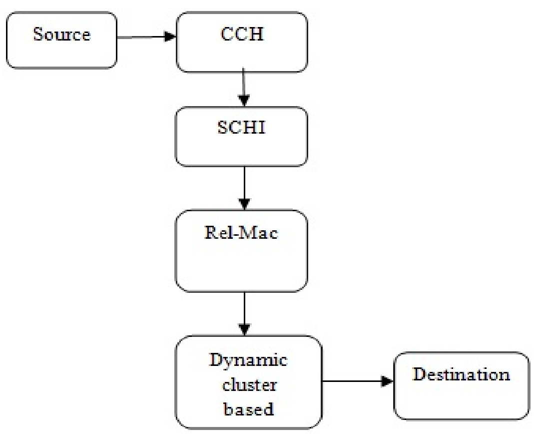

Figure-1. System model.

4. MODULE DESCRIPTION

a) VANET energy reliable MAC

The VER-MAC utilizes the CCH during the SCHI for broadcasting the EMG packet and each periodic/event-driven EMG packet is broadcast twice a SI to increase the packet delivery ratio. If an EMG packet is broadcast in the CCHI (or SCHI), the copy of this EMG packet is scheduled to be broadcast in the upcoming SCHI (or CCHI) by delaying a CCHI (50ms)[7].The purpose of the delay is to avoid the high congestion at the beginning of the CCHI or SCHI. On each SCH, the CCHI and SCHI are divided into *M* transmission slots (TxSlots) which are used for the collision-free service data transmissions. Each node pair performs a WSA handshake to select a TxSlot of a SCH. With six SCHs, the maximum number of TxSlots/SI that can be utilized in the IEEE 1609.4 and the VER-MAC are 6*M* and 12*M*, respectively. Nodes only switch to the selected SCH during the selected TxSlot in order to broadcast their own EMG packets and avoid missing the EMG packets on the CCH in another time. Nodes maintain the Neighbor Information List (NIL) and Channel Usage List (CUL). The NIL stores the SCH and TxSlot used by the neighbors while the CUL shows the available TxSlots of each SCH. Based on the NIL, a node knows when its neighbor is on the CCH in order to perform a WSA handshake. The CUL is used to select the common TX Slot during the WSA [8] negotiation.

Since nodes can be on the SCHs during the CCHI, they might miss the WSA messages used to update their NILs and CULs.

b) VANET efficient dynamic cluster based MAC model

The time delay for an emergency message to be sent from one vehicle in one cluster and reaches vehicles that are located at distance D from the emergency time. If a vehicle has an emergency message, it will contend for the channel access using access class AC3 to send this message. Once this message is received by the cluster head, it starts transmitting this emergency message periodically with enough power reach a distance of (Dc), all other cluster members will refrain from using the channel during this time. When the next cluster head receives this emergency message, it will broadcast the message with a range of (Dc) to reach both the next cluster and the originating CHs. Once the originating CH hears its message back from the neighboring CH, it will stop broadcasting the message with high power but continue the broadcasting to all of its members for several times depending on the application or until the emergency situation is cleared. The emergency message will continue to propagate in the direction of interest for a maximum number of hops (M) depending on the application and the emergency situation.

c) Performance measure

Finally in this section evaluate the performance of the proposed approach based on the VANET efficient dynamic cluster based MAC model with the previous approaches. Compare the approaches based on the PDR, delay, and throughput and simulation time. From the figure 6.1, we compare the performance of IEEE 802.11 and VER-MAC in terms of throughput .From the figure 6.2, we compare the performance of IEEE 802.11 and VER-MAC in terms of delay.

5. ALGORITHM

Step-1: If an EMG packet arrives at the MAC layer, nodes try to broadcast it on the CCH in the current CCHI (or SCHI) and then rebroadcast it in the next SCHI (or CCHI).

Step-2: When a node has service packets to exchange, it sends the WSA including its CUL.

Step-3: Upon receiving the WSA, the receiver selects the common TxSlot and SCH based on the CULs of both sender and receiver. Then, the receiver sends the ACK indicating the selected [TX Slot, SCH] to the sender.

Step-4: The sender sends the RES (Reservation) to confirm the [TX Slot, SCH] selected by the receiver.

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Step-5: Both sender and receiver switch to the selected SCH in the selected TX Slot to exchange their service packets.

Step-6: Neighbor nodes, which overhear the ACK or RES Messages, update their NILs and CULs.

$$\tau_e = b_{e,0} = \left[\frac{1-q_e}{q_e} + \frac{W_e+1}{2}\right]^{-1}$$

$$b_{s,0,0} = \left[\frac{1-q_s}{q_s} + \frac{1}{2}\left(\frac{1-p_s^{L+1}}{1-p_s} + \frac{1-(2p_s)^{L+1}}{1-2p_s}W_{s,0}\right)\right]^{-1}$$

$$\tau_s = \sum_{i=0}^{L} b_{s,i,0} = \frac{1-p_s^{L+1}}{1-p_s} b_{s,0,0}$$

$$P_b = 1-(1-\tau_e)^N(1-\tau_s)^N$$

$$\begin{aligned}
P_{e,suc} &= N\tau_e(1-\tau_e)^{N-1}(1-\tau_s)^N \\
P_{s,suc} &= N\tau_s(1-\tau_e)^N(1-\tau_s)^{N-1} \\
P_{e,col} &= (1-\tau_s)^N\left(1-(1-\tau_e)^N - N\tau_e(1-\tau_e)^{N-1}\right) \\
P_{s,col} &= (1-\tau_e)^N\left(1-(1-\tau_s)^N - N\tau_s(1-\tau_s)^{N-1}\right) \\
P_{es,col} &= P_b - P_{e,suc} - P_{s,suc} - P_{e,col} - P_{s,col}
\end{aligned}$$

$$\begin{aligned}
T_{e,suc} &= T_{e,col} = T_e = EMG + \delta + DIFS \\
T_{s,suc} &= WSA + ACK + RES + 2SIFS + 3\delta + DIFS \\
T_{s,col} &= WSA + \delta + DIFS
\end{aligned}$$

$$\begin{aligned}
E_S = {} & (1-P_b)\sigma + P_{e,suc}T_{e,suc} + P_{s,suc}T_{s,suc} + P_{e,col}T_{e,col} \\
& + P_{s,col}T_{s,col} + P_{es,col}\max(T_{e,col}, T_{s,col})
\end{aligned}$$

$$q_e = 1 - e^{-2\lambda_e \cdot E_S}; \quad q_s = 1 - e^{-2\lambda_s \cdot E_S}$$

$$PDR_e^{1609} = \frac{P_{e,suc}}{N_e\tau_e} = |(1-\tau_e)^{N-1}(1-\tau_s)^N$$

$$PDR_e^{ver} = 1 - (1 - PDR_e^{1609})(1 - PDR_e^{schi})$$

$$E_E = \frac{W_e - 1}{2}E_S + T_e$$

$$E_{D_e^{1609}} = \frac{1}{(\mu_e - 2\lambda_e)} + \frac{T_{cchi}}{2}$$

$$E_{D_e^{ver}} = \frac{1}{2}\left(\frac{1}{(\mu_e - 2\lambda_e)} + \frac{1}{(\mu_e^{schi} - 2\lambda_e)}\right) + T_{cchi}$$

$$N_{s,suc} = \frac{T^{cch}}{E_S}P_{s,suc}$$

$$S_s^{1609} = \min[N_{s,suc}, 6M]; \; S_s^{ver} = \min[N_{s,suc}, 12M]$$

Table-1. Notations used for this algorithm.

Notations	Description
$b_e(t)$	process representing the back off counter value at slot time t.
w_e	contention window
p_e	collision probability
I_e	idle state with an empty buffer
q_e	probability of at least one emergency packet in the buffer
$b_{e,}k$	stationary distribution of the back off state
b_{Ie}	stationary distribution of the idle state
I_s	idle state with an empty buffer for service traffic
q_s	probability of atleast one service packet in the buffer
$b_s(t)$	stochastic processes representing the backoff counter
$s_s(t)$	stochastic processes representing the backoff stage for the service data at slot time t.
$b_{s,I,k}$	stationary distribution of the markov chain
T_S	node transmits a WSA packet in a slot time
$P_{e,}p_s$	collision probabilities
$P_{e,svc}$	probabilities of successful txn for an emergency packet
$P_{s,svc}$	probabilities of successful txn for a service packet
$P_{e,col}$	probability of collision txn from only emergency packet
$P_{es,col}$	probability of collision txn from only both emergency packet and service packet
$P_{s,col}$	probability of collision txn from only service packet
$T_{e,col}$	time the channel is sensed busy during the collision caused by emergency traffic
$T_{s,col}$	time the channel is sensed busy during the collision caused by service traffic
PDR_e	packet delivery ratio of the emergency traffic

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6. SIMULATION

The performance analysis is based on NS-2 simulator. In this paper the protocol developed is C++ and transport protocols used are TCP and UDP.

Table-2. Simulation parameters.

Parameters	Value	Parameters	Value
Data rate	6 Mbps	λs	25pkts/sec
WSA	100 bytes	ACK	14 bytes
EMG	100 bytes	RES	14 bytes
Slot time σ	13 μs	SIFS	32μs
Propagation time δ	1μs	DIFS	58 μs
Retry limit (L)	6	We	8
Number TxSlots$M$	4	Ws,0	16

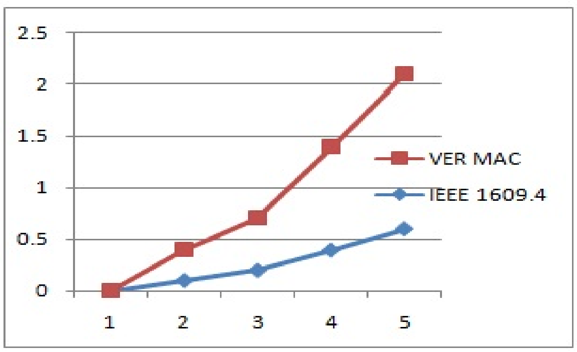

Figure-2. Times in sec Vs Packet Received Delay (pkt)*10000.

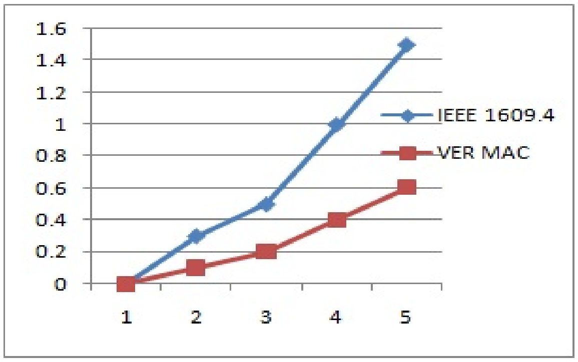

Figure-3. Times in sec vs delay.

7. CONCLUSIONS

Safety and Security is becoming a necessity for VANET applications. As VANETs use wireless technology, it is in a circle defeated by many attacks. This paper has presented VERMAC which is a class of VANET routing protocol for city based environments that takes advantage of the layout of the roads to improve the performance of routing in VANETs. The existing routing protocols for VANETs are not efficient to meet every traffic scenarios. Thus the performance of MAC has been analyzed in terms of PDR and delay of emergency packets. The performance evaluation reveals that VER-MAC outperforms IEEE 802.11.In future, dynamic cluster based model is used to address the complex data structures and more delay of the Emergency packets.

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