Evaluation of Vehicular Ad Hoc Networks on Safety Traffic

Hassan Zoghi, *Member, IACSIT*, Mojtaba Hajali, and Meisam Dirin

***Abstract*—Vehicular Ad hoc NETworks in which no centralized static station or infrastructure are supported is gaining increasing popularity. Due to mobility, the topology of the networks changes continuously and wireless links break down and reorganize frequently. These features cause traditional real-time communication protocols to be inapplicable in a mobile setting.**

The increasing research of real-time communication in Mobile Ad hoc wireless NETworks (MANETs) is to enable distributed applications among mobile nodes in infrastructure-free environments. Vehicular Ad hoc NETworks (VANETs) characterized by nodes with relatively high mobility and various disturbed environments represent a number of remarkable challenge dissimilar to MANETs. Applications of inter-vehicle and vehicle-to-roadside wireless communication that make use of VANETs require reliable communication that provides a guarantee of real-time message propagation. Nowadays, most of researches in VANETs domain concentrate on the development of layered communication protocols.

***Index Terms*—Vehicular Ad hoc NETworks, mobile Ad hoc wireless NETworks, communication**

I. Introduction

Vehicular ad hoc wireless networks (VANETs) are a particularly challenging class of mobile ad hoc wireless networks (MANETs) that are currently attracting the extensive attention of research in the field of wireless networking as well as automotive industries.

Communication in mobile ad hoc wireless networks bolsters various distributed applications among mobile nodes in infrastructure-free environments. Characterised by relatively high mobility, communication in VANETs exhibits stronger challenges than that in other general MANETs. Infrastructure-free environments and higher dynamic network topology cause frequent network partition. Moreover, vehicular ad hoc wireless networks is often deployed by the constraint of roadways where trees, buildings and other assorted obstacles influence the practical transmission effects as compared to generic open fields.

The collaboration of governments, standardization bodies and manufacturers around the world expedites the advance of Intelligent Transportation Systems (ITS)[1].

As an essential part of ITS research, the potential achievement of VANETs research lies on the development of vehicular communication system that enables convenient, stable and economical distribution of data to benefit the safety and comfort “on the road”.

Among various communication applications in VANETs, there is a wide range of important applications involving traffic safety, traffic monitoring and unpiloted vehicles applications demand time restraint communication in Ad Hoc wireless networks. We call these distributed time restraint applications as real-time communication.

As discussed above, highly dynamic nodes and no centre stationary server will cause the collision on wireless medium in the communication of VANETs. On the contention medium, packet delays and losses occur frequently. Real-time communication is easy to be frustrated in these scenarios. Therefore, it is necessary to develop a set of effective mechanism to guarantee the completion of these time-sensitive communications in a restrictive time period [2].

II. Manets

Mobile Ad-hoc networks (MANETs) refer to self-organizing wireless networks consisting of mobile nodes and supporting no fixed infrastructure.

The power limitations depress the range of radio transmission. To relay the message throughout the whole network, each node in MANETs acts as a router. Consequently, MANETs must be a distributed multi-hop network with a time-varying topology.

Owing to self-organizing, MANETs is fittest to be deployed in infrastructure-free environments, such as emergency rescue, military, airports, sports stadiums, campus, disaster management as well as sensor network. Based on such a broad application, the research and deployment of MANETs must increasingly prevail [2].

III. Vanets

With the development of Intelligent Transportation System (ITS), Vehicular Ad-hoc Networks (VANETs) become an emerging research area. As a specific type of MANETs, VANETs have some similar characteristics to MANETs, e.g. short radio transmission range, low bandwidth, omnidirectional broadcast and limited storage capacity [3].

In addition to these similarities, the communication in VANETs meets some particular challenging characteristics [4].

1) Rapid topology changes;
2) Frequent network partition;

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Hassan Zoghi is with the Department of Engineering, Islamic Azad University Karaj Branch, Tehran, Iran (e-mail: h_zoghi@kiau.ac.ir).

Mojtaba Hajali and Meisam Dirin are with the Department of Engineering, Islamic Azad University South Tehran Branch, Iran (e-mail: mojtaba_hajali_eng@yahoo.com, meisam_dirin@yahoo.com).

3) Small effective network diameter;
4) Limited redundancy in time and in function.
5) Position predictability
6) Relatively sufficient power

Position predictability and relatively sufficient power may be utilized to give support to inter-vehicle and vehicle-to-roadside communication, while rapid topology changes, frequent network partition, small effective network diameter and limited redundancy in time and in function aggravate the difficulties to communication in VANETs.

In VANETs scenarios there are three most crucial challenges playing a vital role to achieve stable and effective communication [5] that are

1) How to efficiently utilize limited bandwidth,
2) How to maintain the dynamically fragmented topology
3) How to achieve low-latency in delivering real-time information in various situations.

IV. TBMAC Protocol

Protocols in which stations listen for a carrier and act accordingly are called carrier sense protocols. CSMA (Carrier Sense Multiple Access) is a representative carrier sense protocol. MACA (Multiple Access with Collision Avoidance) [6] is designed for the sender to stimulate the receiver into outputting a short frame, so stations nearby can detect this transmission and avoid transmitting for the duration of the upcoming (large) data frame.

CSMA and MACA, the most renowned contention-based MAC protocols, both employ an exponentially increasing back-off counter to deal with contention and collisions.

In contention-based protocols, fairness to access the medium is promoted and mobile stations do not need to maintain consistent state information for scheduling access. Moreover, there is no restriction required in the number of stations for contention-based MAC protocols.

However, on the other hand, because of the relatively high possibility of collision and contention in package transmission and the hidden terminal problem, they are not suitable for use in real time communication applications of multi-hop ad hoc networks.

Time Division Multiple Access (TDMA) is a collision-free MAC protocol that equally divides the packet delivery time period into a number of slots. Only one station is allowed to transmit data packets in each slot. Thus collision and contention in packet transmission can be avoided. The transmission delay also can be predictable because TDMA demands a known upper bound on the number of stations in the network [7].

TBMAC is based on the above time division MAC protocol that provides mobile stations a predictable probability and time-bound to access the shared wireless medium in multi-hop ad hoc networks. In TBMAC, a certain geographical area is divided into a number of cells, for example, hexagons of equal size, as shown in Fig. 1. Each cell employs a distinct radio channel. Location information, e.g. GPS, is used to ascertain cell boundaries. The advantage of the method is to maximize the spatial reusage of the network.

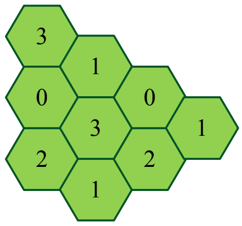

Fig. 1. Cells

In a similar way to the IEEE 802.11 standard, the TBMAC protocol divides the whole time for access to the medium into two distinct time periods:

- Contention Free Period (CFP)
- Contention Periods (CP)

Mobile stations, which have no allocated CFP slots, contend and negotiate an agreement on slot allocation in the CP and transmit data packets using the allocated slots in the CFP. The CFP and CP constitute a TBMAC cycle. In a TBMAC cycle, medium access in the CFP is similar to TDMA, while in the CP it is similar to CSMA.

Unlike the PCF (Point Coordination Function) of the IEEE 802.11 standard, the TBMAC protocol is not dependent on a particular point coordinator. To ensure every station in a TBMAC cell comes to a consistent view of CFP slot assignments, a lightweight synchronous atomic broadcast protocol is exploited.

The TBMAC protocol uses two data structures, Slot Owners and Slot Bitmap. Slot Owners stores mobile stations addresses and the corresponding allocated CFP slots. Slot Bitmap uses two bits to represent the four possible states for each slot: Owner, Other, Collision, Available. The Slot Bitmap, together with source and destination, current slot number, message type, protocol extensions and additional information, makes up the CFP header which is included in the packet a mobile host sends in its CFP slot.

CFP slot management is composed of three parts:

- Allocating a Slot
- Deal locating a Slot
- Inter-Cell Communication

Clock synchronization is necessary for the TBMAC protocol to achieve slot management. GPS facilitates to establish clock synchronization of all mobile stations in the network with microsecond-level precision.

The TBMAC protocol handles slot allocation in these potential scenarios as follows [8]:

- One station enters or powers on in an active cell.
- Two or more stations attempt to join an active cell at the same time.
- One station enters or powers on in an empty cell.
- Two or more stations attempt to join a cell nearly simultaneously.

Roughly, when a joining station is in need of slot allocation, it will monitor the current state of the cell, then floods requests and negotiates an agreement on slot allocation in the CFP. On the other hand, a set of atomic broadcast metrics is utilized to deal with Slot Deal location in the TBAMC protocol.

If there is a demand for inter-cell communication between two mobile stations in adjoining cells, two particular inter-cell CFP slots will be allocated to the two cells respectively. In a new version of TBMAC protocol, an

Inter-cell Communication Period (ICP) is proposed especially for message exchange between cells.

Apart from the CFP and the CP, the new scheme of TBMAC assigns a time period especially for inter-cell message exchange. Once a mobile node attempts to send packets to another node in adjoining cell, it issues a request.

Then the node can carry out transmission on condition that the desired ICP time slots are assigned to it. In this case, a TBMAC round comprises One CFP, one CP and one ICP. To avoid potential collisions in the ICP, a mechanism needs to be exploited to elect a gateway node to preside over the communication with certain nodes [4].

V. VANETS SIMULATION

A. Vehicle Mobility

To simulate VANETs, one of the key factors is the vehicle mobility model that not only determines the location of vehicles but also influences the network topology, network connectivity and the access to medium [9].

1) Vehicle velocity

The speed of a vehicle determines the location change of the vehicle in a certain time. The various speeds of vehicles cause the change of network topology. In this project we set the bound of vehicle speed from 0 to 100 km/h.

2) Acceleration and Deceleration

In the real world, there are few scenarios in which a vehicle keeps the same speed for a long time. So we introduce the concept of acceleration and deceleration into this work.

3) Interdependent movement

It is well known that the movement of vehicles is constrained not only by the shape of the road but also by neighboring vehicles. The speed limitation of a vehicle should be considered as a mixture of the highest speed bound and the front vehicle speed.

4) Simplified modeling factors

Apart from these highlighted specifics described above, we make some unconcerned factors straightforward so as to simplify the complexity of the whole system. For example, some vehicle motions such as lane change and overtaking other vehicles.

B. Roadway Layout

As mentioned above, the behaviour of nearby vehicles and the speed limitation impact vehicle motion. Moreover, vehicle motion must be constrained to roads. The boundaries of roadways confine the movement of vehicles to a predefined route. Due to the constrained route, the network topology and the routing pattern can be better predicted. The roadway is designed as a two-lane street, and each lane supports an opposite driving direction. Because we mainly want to examine TBAMC slot management influenced by the vehicle speed and location, we make a simplified assumption that the roadways are straight, the terrain is tacit to be constantly flat and the junction of roadway is ignored, as plotted in Fig. 2.

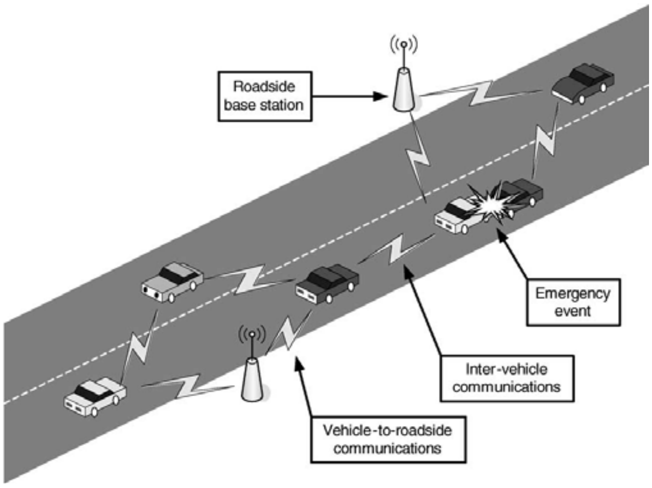

Fig. 2. Layout of roadway

C. Roadside Base Station and Cell

VANETs combine vehicle-to-vehicle communication and roadside-to-vehicle communication. Vehicle-to-vehicle and roadside-to-vehicle communication relies on the infrastructure-less network structure. However, different from other general MANETs, a roadside base station that plays a fixed node in VANETs normally acts as a master, namely a coordinator, in the infrastructure-less network structure. The range of radio transmission determines the size of the area that a roadside base station covers. Theoretically, a cell and all of its contiguous cells should be covered by the radio transmission from the base station in itself. The cells could be shaped as a cellular structure that is illustrated in Fig. 3. Each cell contains one and only one roadside base station. The number of vehicles is dynamic based on the movement of vehicles [4].

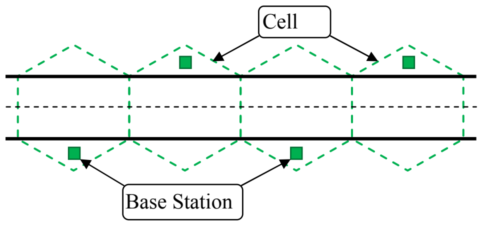

Fig. 3. Base stations and cells

D. Send and Receive Messages

Both vehicles and base stations are nodes in VANETs communicating with each other by sending and receiving packets.

1) Intra-cell communication

According to the TBMAC protocol, access to the wireless medium for intra-cell communication is divided into CFP and CP. The CFP and the CP are also equally divided into a series of time slots. The periodicity of packet transmission within a cell is defined within the CFP. Thus time slots in the CFP are assigned to vehicles in order that each vehicle can send packets in a dedicated and predictable duration. Moreover the possibility of collision can be avoided to a large degree. Newly arriving mobile nodes in a cell negotiate the allocation of CFP slots in the CP.

2) Inter-cell communication

If a vehicle attempts to send a message over cell boundaries, it will send the message to the base station in the same cell. The base station, playing a role as a gateway, relays the message to the base station in the destination cell. At last the terminal vehicle gets the message from the base station of its own cell.

Furthermore, the new version of the TBMAC protocol assigns an Inter-cell Communication Period (ICP) especially for inter-cell communication, as illustrated in Fig. 4. Base stations can employ the time slots in the ICP to perform inter-cell communication [7].

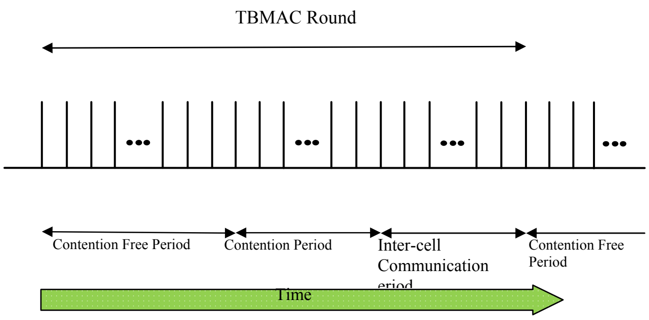

Fig. 4. TBMAC round structure

E. VANETs Simulation Structure

To integrate the roles and their behavior described above, we build an organization structure to exhibit the relationship between these entities of VANETs, as shown in Fig. 5 (Appendix). Roadway, cell, vehicle and base station are four entities in simulation. We assume one cell only contains a single base station. The roadway has two unidirectional lanes and stretch though a number of cells.

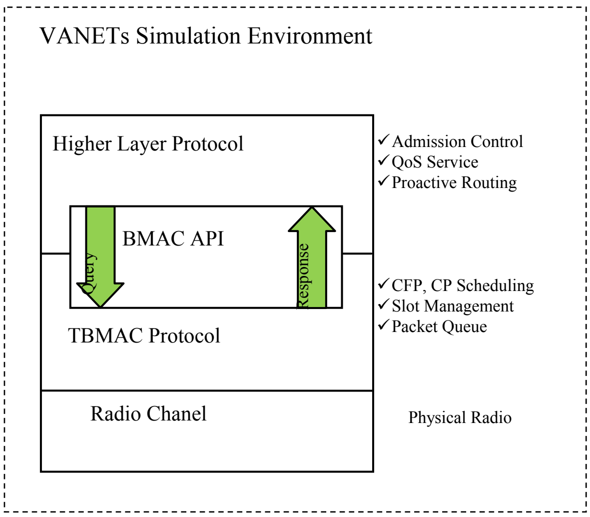

Fig. 5. TBMAC API

VI. TBMAC Application Programming Interface

On top of the traffic simulation proposed above, we attempt to investigate the impact of the TBMAC protocol performing on both the MAC layer and high layers. Consequently, we can evaluate the performance of the TBMAC protocol accurately. In network simulation the TBMAC protocol is responsible to control the access to the medium, i.e. initiate a set of time slots and manage slot allocation. One obvious advantage of this TBMAC approach is to minimize the occurrences of collisions among mobile nodes in accessing wireless channels.

However, how to perform slot management is decided by the layers above the MAC layer, such as Quality of Service (QoS) layer, Routing layer and Admission Control layer. For example, when a car comes into a new cell, Admission Control layer will monitor this event and send a request to MAC layer to ask for allocating CFP slots to the car. As for how many CFP slots should be allocated to the car, that demand will be proposed by the QoS layers[8].

To sum up, the ideal TBMAC protocol model should allow new models in other layers to be aggregated on top of itself with ease. Therefore, it is necessary for the TBAMC protocol to provide an application programming interface (API) to facilitate the communication with other layers, as illustrated in Fig. 6.

VII. Conclusion

Traffic simulation is a complex system that attracts a lot of research interest. This project follows some sophisticated theoretic, algorithms and approaches to implement a microscopic small-scale traffic simulation. Some functional limitations in this simulation made it unsuitable to perform large wireless network simulation.

Thereby, the first step of future work is to enhance the vehicular mobility model. For instance, to make the traffic simulation more realistic, we should add the overtaking and lane change functions. The terrain should be diversiform. The diverse terrains pose different effects on the speed of the vehicle.

The development of TBMACs in progress to boost the improvement of TBMAC is another important task in the future. The TBMAC protocol has close relationship with higher layer protocols. It is necessary to provide a interface so as to facilitate the communication between MAC layer and higher layers.

In addition, communications in VANETs demands multi-layer collaboration. The advance of higher layer (e.g. some routing protocols) also will speed up the progress of the TBMAC layer.

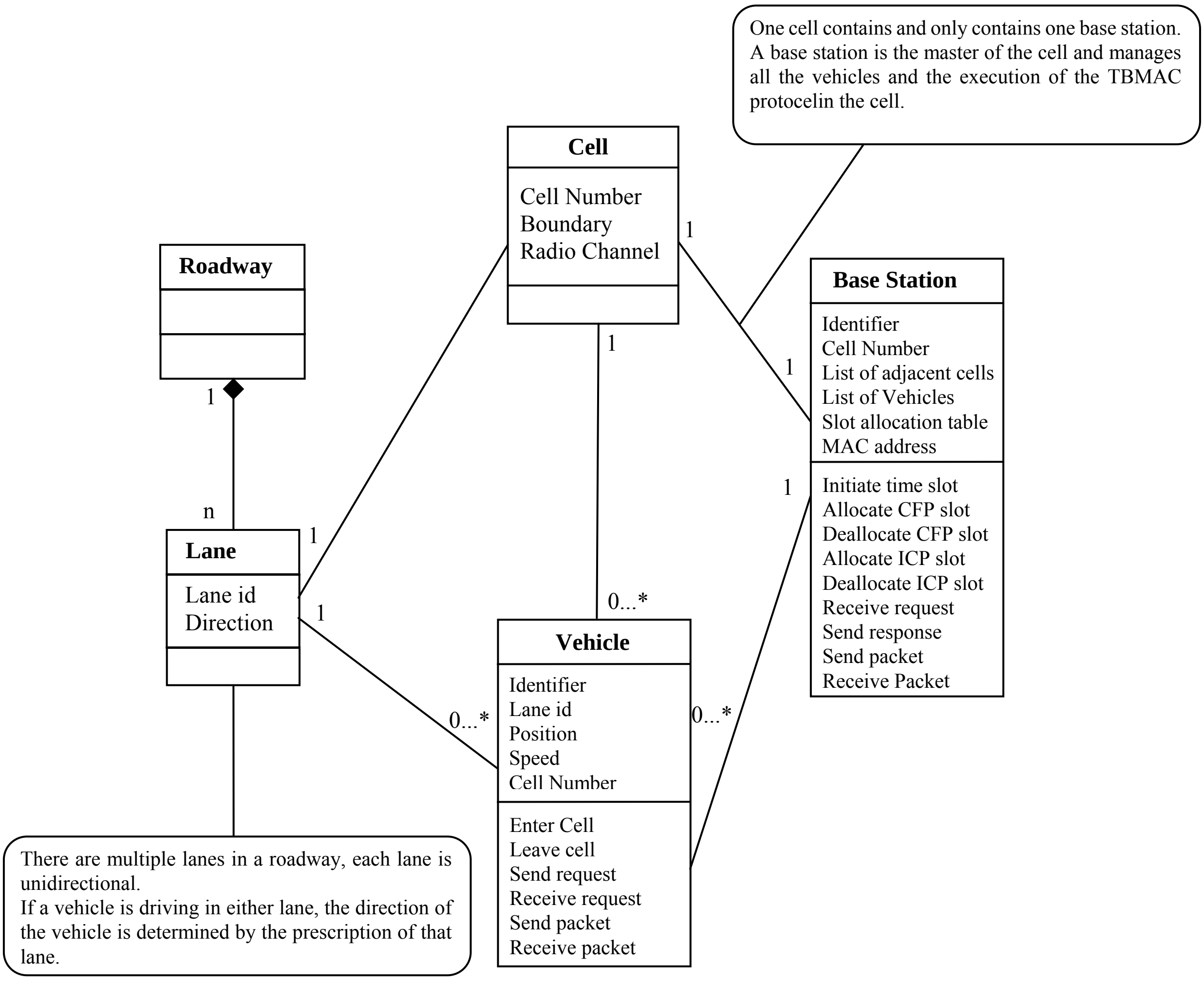

Fig. 6. VANETs Structure

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