www.czasopisma.pan.pl PAN www.journals.pan.pl
POLSKA AKADEMIA NAUK
jet INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2010, VOL. 56, NO. 4, PP. 433–444
Manuscript received May 5, 2010; revised July 2010. DOI: 10.2478/v10177-010-0059-3

A Study and Review of Self Managed Vehicular Networks

Johnson I. Agbinya, Gina P. Navarrette, and Hanan Al-Ja'afreh

***Abstract*—An Intelligent transportation system (ITS) focuses on application of smart vehicles. The vehicles are equipped with significant computing, communicating and sensing capabilities to provide services to travelers or the goal of providing safety massages in emergency situations. Vehicular network may also be used for Internet access, inter-passengers communications and entertainment. To understand the behavior of such networks as well as to provide good services to the travelers many issues have to be managed, some of them are: call handover between vehicles in vehicular network, speed Vs capacity, security of call, network topology, and network fragmentation. In this paper we study such vehicular networks and explain these issues and the related work. Detailed study of practical node mobility models based on mobility states and the quality of practical links based on received signal strengths are used as inputs for system capacity studies. Experiments were run in Sydney based on drive tests with mobile terminals deployed on them. Then some new ideas for managing the vehicular networks are proposed.**

***Keywords*—Intelligent transportation system, Vehicular Network, Vehicle-to-Vehicle communication, Roadside-to-Vehicle communication.**

I. INTRODUCTION

A VEHICULAR NETWORK (VN) is a communication network organizing and connecting "smart" vehicles to each other and with the other mobile and fixed network. Each vehicle is equipped with devices like sensors and actuators that support Vehicle-to-Vehicle communication (V2V) and Roadside-to-Vehicle (R2V) communication; not every vehicle will have these capabilities. Due to the gradual nature of market penetration, only a fraction of vehicles will be instrumented, at least for the next several years [1], [2].

Several wireless network types can be used for creating vehicular networks, including Wireless Wide Area Networks (WWAN), Wireless Metro Area Networks (WMAN), Wireless Local Area Networks (WLAN) using roadside base stations, and vehicular ad hoc networks (VANET) using V2V communications. These technologies offer different tradeoffs in cost and performance [3], [4]. There are several possible network architectures for creating vehicular networks. Three alternatives include a pure wireless V2V ad-hoc network where information can be exchanged without the need of a costly infrastructures, a wired backbone with wireless last-hop, or a hybrid architecture using V2V communication that does not rely on a fixed infrastructure, but can exploit it for improved performance and functionality when it is available [3].

It is a challenging task to manage networks in a dynamic environment due to the characteristic of high mobility rate, high relative speed, different drivers' behaviors and occurrences of unpredictable link failures. Management issues include call handover (routing) between vehicles, speed (mobility) Vs capacity management, security of calls, network topology, link stability, network fragmentation and traffic management.

This paper is arranged as follows: in the second section, call handover management between vehicles in VN is explained. Speed (mobility) Vs capacity management is discussed in the third section. Security of calls management is expressed in the fourth section; network topology is highlighted in fifth section, Link stability is described in sixth section, Network fragmentation is presented in seventh section, Traffic management is introduced in eighth section and finally the paper is concluded in section nine.

II. CALL HANDOVER BETWEEN VEHICLES IN (VN)

All VANETs are implementations of mobile ad hoc networking technology to facilitate (V2V) and (V2R) communication. A vehicle in VANET is considered to be an intelligent mobile node capable of communicating with its neighbors and other vehicles in the network [1].

Therefore in VANET vehicles can self-organize and connect within a network to exchange information and messages that make the driver aware of the condition of the road especially in emergency situation. This intelligence is extended to any terminals in the vehicle which should be able to connect to networks within the environment of the vehicle and to change its points of access as network conditions change. To expedite the information dissemination in VANET, network connectivity is needed [5]. This means, a message from a source vehicle should be able to reach the maximum number of the vehicles on the road segment and the links should be maintained for required data transfer. In [5], authors considered the one-way street and the two-way street scenarios in presenting a theoretical framework for analyzing the number of vehicles required for distributing traffic information in a self-organizing vehicular network and to determine the critical transmission range for a particular connectivity level. In One-way Street (Figure 1), the network connectivity depends on the transmission range of each instrumented vehicle, which is called Communication Capable Vehicle (CCV), and the penetration ratio which represents the density of the CCVs which are randomly and uniformly distributed along the road segment [3], [4].

J. I. Agbinya, G. P. Navarrette, and H. Al-Ja'afreh are with the Centre for Real Time Information Networks (CRIN), Faculty of Engineering and Information Technology, University of Technology, Sydney (UTS), PO Box 123, Broadway NSW 2007, Australia (e-mails: johnson.agbinya@uts.edu.au, Gina.Navarrete@optus.com.au, Hanan.A.Al-Jaafreh@student.uts.edu.au).

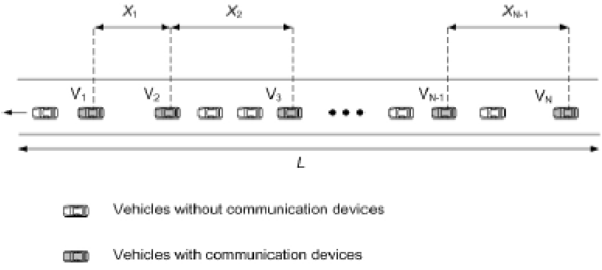


Fig. 1. One-way street scenario [5].

These parameters are related to each other according to equation (1):

$$P_c = (1 - e^{pz})^{N-1} \tag{1}$$

Using two wireless interfaces IEEE 802.11 and IEEE 802.16 (Broadband Wireless Access) with WiMAX devices, respectively in the analysis, they observed that the connectivity probability should increase as the transmission range and the CCV density increase. In other words the higher the number of CCVs on the road segment, the higher the probability of having a connected network.

If the distance between any two consecutive CCVs is larger than the transmission range then a link is broken and the opposing vehicles on a two-way street can be used to improve the connectivity probability.

To increase the connectivity probability to deliver data from the source to the destination, a new routing strategy is used on the two-way street; this strategy is called store-carry-forward. Using such a strategy in case of a broken link, the extraneous nodes on both sides of the street do not drop the data packets when the connection is broken. Instead, they still carry the data while moving and wait for a suitable node to forward the data [5]–[7].

In ad hoc network, to manage a network topology in a self organizing manner a clustering algorithm is applied. A cluster is a set of connected nodes with a specified node responsible for cluster management called cluster head [8], [9].

In a heterogeneous networking environment where different technologies are integrated, often both wired and wireless. (e.g., GSM/GPRS and UMTS cellular networks, Wi-Fi, Bluetooth, and WiMAX), vertical handover is used to switch the current point of attachment from one access point to another [1], [10].

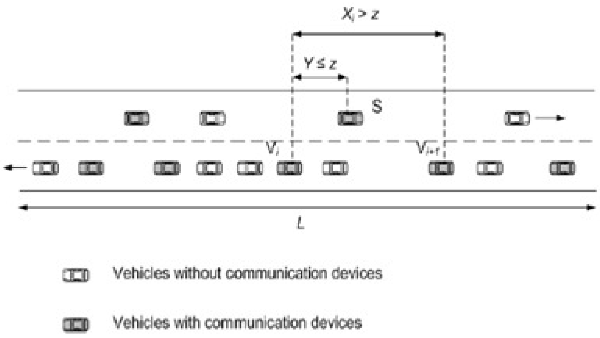


Fig. 2. Two-way street scenario [5].

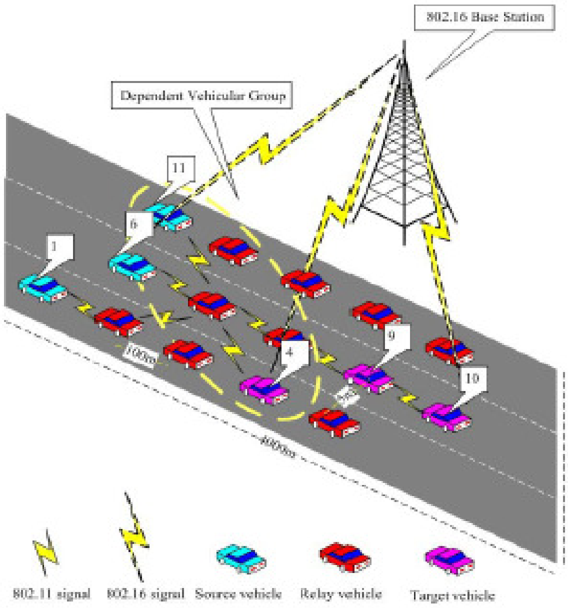


Fig. 3. Heterogeneous vehicular network [1].

In [1], a Heterogeneous Vehicular Network (HVN) Architecture is proposed with the introducing of mobility pattern aware routing protocol (MPARP) for HVN which can provide reliable V2V communication service. In this Architecture, a vehicle is equipped with two wireless interfaces IEEE 802.11 and IEEE 802.16 that can communicate directly with each other or via multiple hops transmission in the form of VANET. For those vehicles associated with the 802.16 base stations (BS) on the roadside, they can communicate with farther vehicles via a relay base station. Using WiMAX technology provides high data rate, strong Quality of Service (QoS) capabilities, large network coverage, cheap network deployment and maintenance costs [11].

In the vehicular network, broken links may occur due to congestion where the massage traffic is so heavy that it slows down network response time, in this case the handover is done only for a few data packets and another route is needed to be established to complete the task. Other effects occur due to the congestion including queuing delay, packet loss, collisions or the blocking of new connections. This situation is more noticeable in metropolitan areas where nodes move with high speeds in different streets, which are surrounded by large building. The large building causes a very short window of communication between nodes [4], [12]. Early studies deal with this problem by embedded techniques to reconnect the broken link quickly with low overhead, in [12] Connectionless Approach for Vehicular Networks have employed to help handover the data, but does not consider data loss in the forwarding procedure. The authors in [4] put solutions for the weakness in this approach in order to minimize the packet drops in case of traffic congestions.

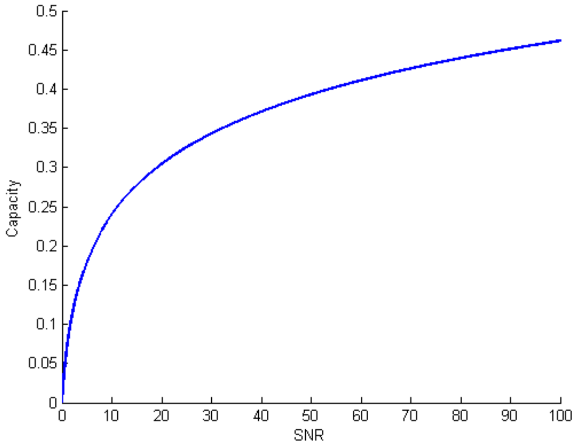


Fig. 4. Doppler Effect curve.

III. SPEED VS CAPACITY MANAGEMENT

The relationship between the Capacity of links and the signal to noise ratio is expressed through Shannon's popular equation (2)

$$C = B\log(1+SNR) \tag{2}$$

The velocities of nodes affect signal and noise power.

Doppler Effect: is a phenomenon observed when there is a relative motion between the source and the observer which results in an apparent upward shift in frequency when the observer and the source are moving toward each other, while an apparent downward shift in frequency is caused when the observer and the source are moving away from each other. In other words, the frequency of the received signal will not be the same as the source frequency [13] The amount of the carrier frequency change due to the Doppler Effect depends on the relative motion between the source and observer and on the speed of dissemination of the wave.

Doppler shift in frequency is expressed by [14]:

$$\Delta f \approx \pm f_0 \frac{v}{c} \tag{3}$$

Where Δf is the change in frequency of the source seen at the receiver, f_0 is the frequency of the source, v is the speed difference between the source and transmitter and c is the speed of light. The new carrier frequency is

$$f = f_0 \pm \Delta f \tag{4}$$

As an example of the effect of Doppler on the channel quality in case of high speeds, the throughput features of the carrier at varying speed is characterized for a WLAN in a vehicular network scenario [15]. As described in [15], an 802.11b access point was placed in a stationery position on a bridge over a main roadway. A vehicle was equipped with an 802.11 enabled laptop and GPS receiver. Data traffic monitoring software was used to collect the speed, link quality and throughput measurements for four different vehicle speeds of 50, 65, 80 and 100kmph. The results show that the reachable throughput decreases noticeably from 520kbps at 50kmph to 250kbps at 100kmph as the speed of the vehicle increases.

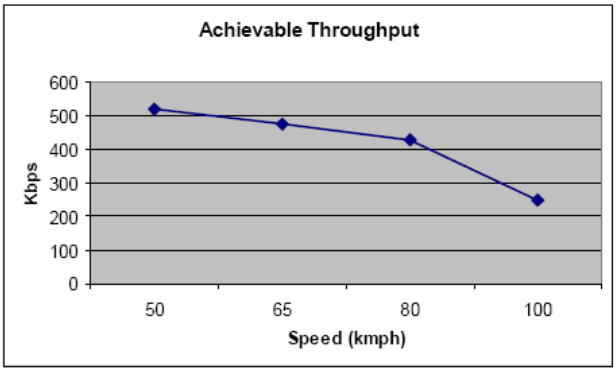


Fig. 5. Throughput of infrastructure communications at high speeds [15].

Mobility: There are three specific keys for vehicular mobility: node velocity, movement pattern, and node density.

Node velocity: In VANETs, the potential node velocity is one of the most important aspects of mobility which introduce more challenges to the communication system. Node velocity varies from zero to the stationary road side units to over 200 km/h in for vehicles on highways. For very high node velocities, the quite small transmission range of several hundred meters results in a very short window of communication [16].

Simultaneously, less topology changing results in case of moderate relative velocities for vehicles driving in the same direction. The Doppler effect has a main impact in case of high relative velocity transceivers have to handle with this effect because the link layer cannot expect when a connection is disturbed, link failures will happen frequently. For low relative velocities with almost no mobility, the network topology is much more stable. Nevertheless, slow movement in the vehicular range usually means a very high vehicle density, which results in, medium access problems, high noisiness and so on. For this reasons, very scalable communication solutions are required [16]

Movement Pattern: The way the vehicles move and the road structure is important key vehicular network mobility. Inside cities, the road density is relatively high and large buildings cause a very short window of communication. In the rural areas due to the small number of vehicles on the road the probability to create a connected network is not high. In highways: where roads have very large segments the movements are semi one-dimensional. The overall directions of roads change less frequently than the other types.

Node Density: In the vehicular environments the node density is related to the type of road and the time, in other words, the node density is high during the daytime and on the cities and highway roads where more vehicles are distributed along the transmission range for instantaneous massage forwarding and it can cope with network fragmentation. However, instantaneous message forwarding becomes unworkable if the node density is low and more sophisticated information propagation will be needed; moreover store and forwarding mechanism can be used with the probability of massage rebroadcast.

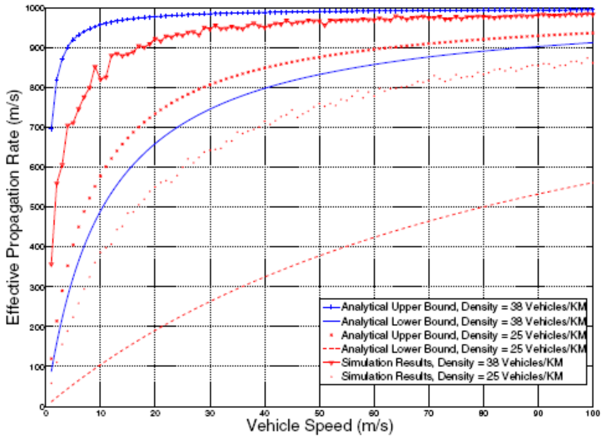


Fig. 6. Message propagation rate as vehicle speed increases at fixed density [7].

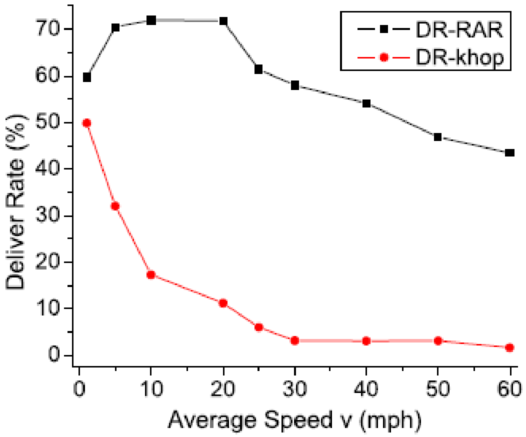


Fig. 8. Delivery rate under different speeds [17].

In [7], the massage propagation is expressed as a function of vehicle speed, traffic density and radio range. At a fixed density of vehicles of 25 vehicles/km in the network, an increase in traffic speed from 0m/s to 20m/s results in a corresponding increase in message propagation rate from 0m/s to at least 200 m/s.

On the other hand, the relation between the relative speed and the links broken is studied in [1]. In Figure 7, the link break occurs frequently when the relative speed increases. Then using another technology like IEEE 802.16 to forward the data increases the capacity.

In the hybrid vehicular network architecture where road side units (RSU) are implemented at the road intersections and different locations act as a gateways to provide internet access to the vehicles on the roads, a Roadside-Aided Routing (RAR) method is proposed and evaluated under different speeds in [17].

Simulation show in figure 8 and figure 9 that RAR performs very well under high mobility with its high delivery rate and low and constant overhead with the increasing of the average speed, which means improving the capacity of data delivery.

The performance of ad hoc V2V was studied in [18] by measuring the V2V network capacity as the number of communication tasks sustained by the network using fixed numbers of wireless channels without causing interference or data collision. The analysis shows that the capacity increases in the congestion areas [18] because of the best reuse of the resources in the congested area where large building causes a very short window of communication. Another observation is V2V communication capacity can be increased by using a simple strategy which filter the communication tasks where requests can be handled by the infrastructure instead of the ad hoc network if the length of the requests is above a certain threshold that is numerically determined [18].

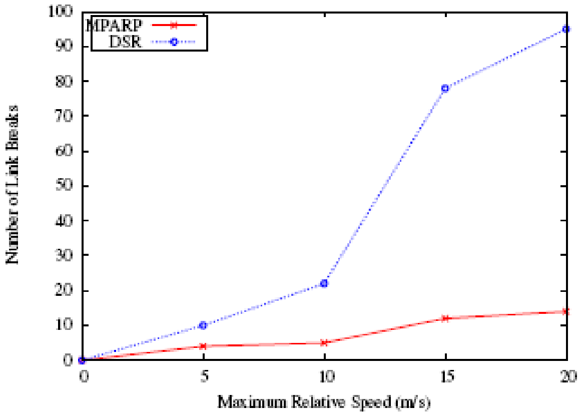


Fig. 7. Number of link breaks [1].

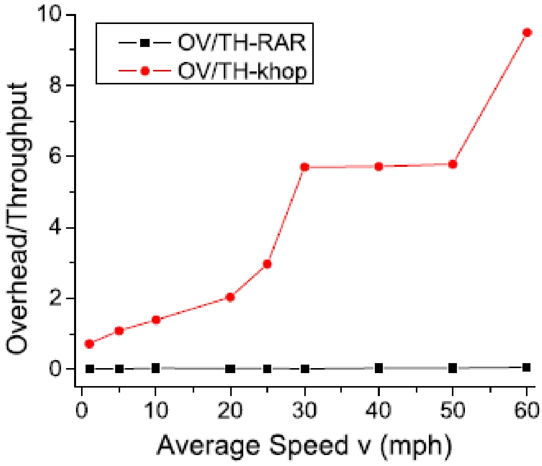


Fig. 9. Overhead under different speeds.

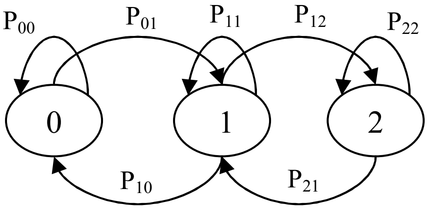


Fig. 10. Three-state vehicle velocity model.

IV. MOBILITY STATE MODELS

In a recent study by the authors based on vehicular networks in Sydney, a system state movement frameworks was used.

The network topology mainly changes according to the velocity of the vehicles. The velocity state model is used to estimate how often the position of the nodes changes before the links are broken. These links form the network topology, which is used to determinate how the nodes communicate. Different state models are considered according to the type of vehicle in consideration and their velocities.

There is a huge set of literature on mobility in ad hoc network settings. Most of the mobility models are theoretical and not practical for vehicular network applications. In our study we have proposed mobility models that have practical applications and used them for our experiments. The concept of mobility state is introduced and studied.

A. *Car Mobility State Models*

In the case of cars, a three state model is used, as Figure 10 illustrates. These states are: when the car is stationary, the car is moving with constant velocity and when it is changing velocity. The probability of passing from one state to another is represented by equation (5).
State 0 is when the vehicle is not moving.
In state 1 the vehicle is changing velocity.
In state 2 the vehicle is moving at a constant velocity.
Therefore the probability of passing from one state to another can be represented in the following matrix:

$$P = \begin{bmatrix} p_{00} & p_{01} & 0 \\ p_{10} & p_{11} & p_{12} \\ 0 & p_{21} & p_{22} \end{bmatrix} \tag{5}$$

A more detailed four states configuration (Figure 12) may be appropriate under certain practical conditions. This form considers varying velocities of the vehicles. In both models the percentage of time in which the vehicles remain in each state and the percentage of time in which the vehicle pass from one state to another are of importance.

Based on these models if for example the area of coverage of an APs used is 3 km (eg. mobile WiMAX) [19], then the link between the two AP1 and AP2 is expected to break when the distance between them is more than 6 km, as in Figure 11. However, the interference from the environment which can reduce this distance is not considered here.

From the velocity state models, an estimation of the frequency at which the topology changes from states 0 to 2 can be estimated. In state 0 it is not necessary to find a new topology, as the vehicles are not changing positions; the topology remains the same. In state 2, it is necessary to know the value of the velocity (vector with magnitude and direction). Here, the worst-case scenario occurs when the vehicles are moving in opposite directions and at their maximum speed. For instance, two vehicles moving at 110 km in opposite directions along a highway will lose the link connection after 98 seconds given by:

$$t = \frac{6km}{220\frac{km}{h}} = 98s$$

The second-stage model is the four-state velocity model.
In Figure 12: State 0 is when the velocity of the vehicles is 0 km/h.
In state 1 the vehicles are moving at very low velocity (0 km/h to 40 km/h).
In state 2 the vehicles are moving at high velocity (40 km/h to 80 km/h).
In state 3 the vehicles are moving at very high velocity (above 80 km/h).
Then the probability of changing from one state to another is represented in equation (6)

$$P = \begin{bmatrix} p_{00} & p_{001} & 0 & 0 \\ p_{10} & p_{11} & p_{12} & 0 \\ 0 & p_{21} & p_{22} & p_{23} \\ 0 & 0 & p_{32} & p_{33} \end{bmatrix} \tag{6}$$

In equation (6), the zero probabilities represent impossible state transitions. For instance, it is not possible to pass from the state 0 to the state 2, before it is necessary to pass from state 1.

With this four-stage model, it is easier to estimate how frequent the topology of the network needs to be found compared with the three state models. This is because the velocity of the vehicles is well known at each stage. The worst-case scenario for stage 1 in this model is given by:

$$t = \frac{6km}{80\frac{km}{h}} = 270s$$

From these results, the lower the velocities of the APs are, the more stable the network topology structure is. However, it is affected by environmental effects, such as obstacles and buildings. When that happens it is necessary to measure the strength of the signals in order to maintain the links between the APs.

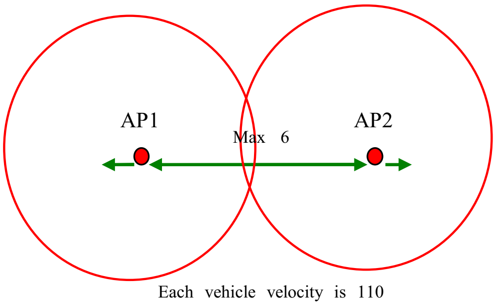


Fig. 11. Link between two APs.

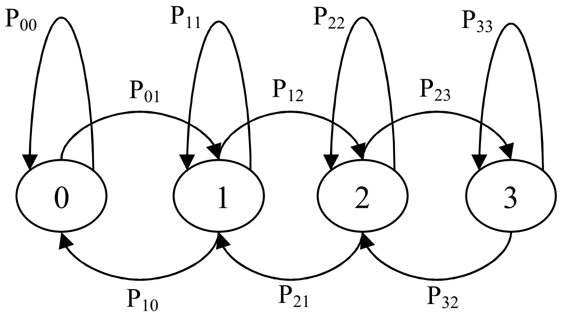


Fig. 12. Four-state vehicle velocity model.

B. Train Mobility State Model

A two-state model is used for train mobility (Figure 13): In state 0 the train is stationary, taking on or depositing passengers. In state 1: when the train is moving.

The transition probability from one state to another is represented in the equation (7):

$$P = \begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix} \tag{7}$$

In this case, the system structure of the train and the train timetable is used to build the network topology for different times during the day. For all the previous stage models, the values of the probabilities of the matrixes are represented by equation (8):

$$p_{ij} = \frac{t_{ij}}{\sum_{l=0}^{N}\sum_{l=0}^{N} t_{kl}} \tag{8}$$

where p_{ij} is the value of the probability to change state, t_{ij} is the amount of time that the vehicle takes to move from one state to another and $\sum_{l=0}^{N}\sum_{l=0}^{N} t_{kl}$ is the sum of the time of all probabilities.

To determine the values of the probabilities for both road vehicles and trains mobility test was conducted in cars and trains in Sydney using the busy airport train route. In the case of vehicles, a drive test around an area in Sydney, Australia was undertaken. For these experiments the available mobile network that provides greater range of services to users today is the third-generation network (3G or UMTS). The experiments are therefore based on UMTS network for the drive test. To collect the data, the Nemo software was used and a USB is used to connect the Nokia 6630 and 6680 and Samsung Z107 measuring NEMO box, which has many USB ports to connect the phones, signal strength scanner and the GPS system. The GPS system is used to measure the position of the vehicle and therefore also measures velocity. It is the main component used in this chapter. Then, the Nemo software allows collection and analysis of the data. Figure 14 shows the selected suburbs where the drive tests were undertaken.

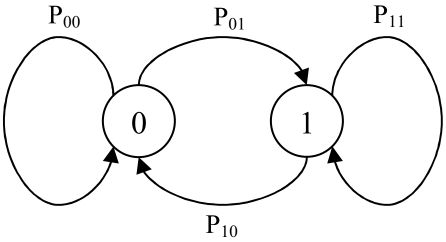
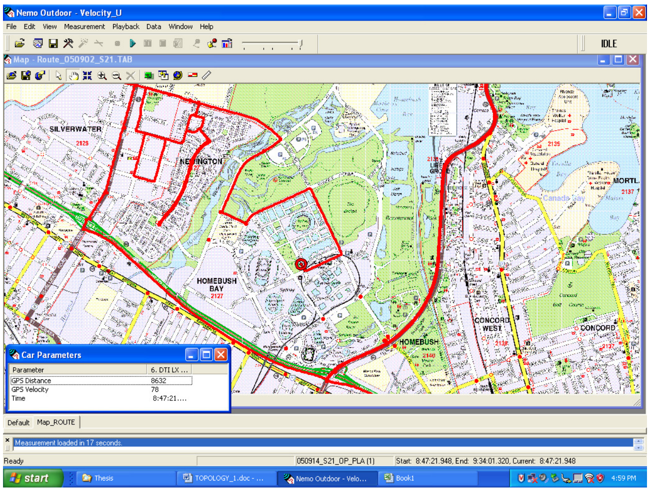


Fig. 13. State model in the case of trains.

Fig. 14. Selected area for drive test.

As the figure shows, the area presents different kinds of roads such as freeway (#2 oval in the figure), high-speed roads with traffic lights (#3 oval in the figure) and low-speed roads (#1 oval in the figure). The area also introduces different kinds of mobility structures such as random, Manhattan (#1 oval in the figure), chain and cross. The workspace that is used in Nemo to take the measurements is illustrated in the Figure 15. In the figure, the red line shows the roads that were driven along, and the red point represents the car. At the bottom left hand part is a window showing the velocity, the time and the driven distance. Table 1 shows how the data is collected. The distance is given in metres, the velocity in kilometres per hour and the time is the actual time in which the measurement is taken.

This recorded information can be replayed many times, and it helps to check the data more accurately. The data collected



Parameter	6. DTI LX ...
GPS Distance	8632
GPS Velocity	78
Time	8:47:21....

Measurement loaded in 17 seconds.

Ready 050914_S21_OP_PLA (1) Start: 8:47:21.948, End: 9:34:01.320, Current: 8:47:21.948

Fig. 15. Vehicle moving in an urban area.

TABLE I
COLLECTED DATA

Parameter	6. DTI LX ...
GPS Distance	8632
GPS Velocity	78
Time	8:47:21....

is used in an Excel document to then estimate the probability in the matrices for the velocity-state models.

Table 2 shows an example of the measurements collected for the three state model. The data was collected for the three-state vehicle velocity model presented in Figure 10. The time shown in each cell is the time recorded during the different moments of the drive tests and it is given in seconds. Each column corresponds to one of the three states.

From Table 2, it can be seen that the time during which the vehicle is stationary is 205.65 seconds. The total time is 1226.03 seconds. Then, the probability p_{00}, when the APs are not moving for the equation (39) presented in the state model of the 0 is:

$$p_{00} = \frac{205.652}{1226.032} = 0.16773$$

Table 3 presents an example of the data that is collected for the four-state vehicle velocity model. Each cell contains the time in seconds recorded for different drive tests and each column corresponds to one of the four states.

Equation (8) is used to calculate the value of the probabilities. The probability that the vehicle velocity remains between 0 km and 40 km is:

$$p_{11} = \frac{352.572}{1226.032} = 0.30119$$

Then, the same process is repeated to calculate the rest of the probabilities except for the state transitions probabilities between stages. For these transitions, it is necessary to conduct more measurements, and this will be left for further research.

In the case of the train scenario the measurements were conducted along the train line to Campbelltown from Central Station, between 7.30 p.m. and 8.30 p.m. in Sydney, Australia. The resident time in each station and the time taken to travel between stations were measured and are presented in Table 3. From the data collected, the equation (8) shows the values:

$$P = \begin{bmatrix} 0.1 & 0.3 \\ 0.3 & 0.3 \end{bmatrix}$$

TABLE II
RECORDED FOR 3-STATE VEHICLE VELOCITY MODEL

Not moving (sec)	Changing velocity (sec)	Constant velocity (sec)
29.576	8.652	9.9
2.501	25.32	60.797
3.328	41.061	10.07
12.975	41.06	
12.454	12.454	
10.860	32.877	
10.220	13.588	
31.192	8.209	
60.102	68.816	
17.809	10.146	
14.634	48.388	
	79.345	
	17.448	
205.65	407.364	613.015

TABLE III
TIME RECORDED FOR THE FOUR-STATE VEHICLE VELOCITY MODEL

	0 km	0 km - 40 km	40 km - 80 km	80 km+	Total time
	29.576	7.186	11.366	54.116	
	2.501	25.3	40.837		
	3.328	10.979	17.361		
	12.975	23.7	28.768		
	12.454	12.454	7.169		
	10.86	32.877			
	10.22	13.588			
	31.192	8.209			
	60.102	109.035			
	17.809	48.388			
	14.634	1.72			
		21.411			
		20.277			
		17.448			
Total time	205.65	352.572	105.5	54.116	717.8

From this analysis, it is important to know the speed of the vehicles in order to estimate how frequent the topology changes. It is also necessary to sense the direction in which the vehicles are moving in the area of communication in order to maintain the communication and the quality of the signal. The velocity state models show that it is possible to calculate the probability of vehicles mobility (stationary, moving, moving at different velocities) in an area. This information can be used to estimate how often the location of the moving APs needs to be updated. The location changes during the time are used to create the new topology before it dramatically changes and therefore avoid data losses.

C. *Type of Mobility Analysis*

Different cities or parts of the cities have diverse road structures, according to the shape they present. These structures are considered as a type of mobility. For example, the chain mobility structure describes the type of mobility for a freeway. Road structures followed by vehicles impact the type of mobility of the vehicles carrying APs, in the dynamic network. Consider the examples in the next set of Figures. In

TABLE IV
TIME RECORDED FOR THE TRAIN-STATE VEHICLE VELOCITY MODEL

Station no.	Travel time (sec)	Resident time (sec)
0	-	-
1	100	30
2	90	90
3	315	26
4	295	31
5	155	25
6	158	35
7	385	30
8	161	35
9	307	30
Total	1966	332

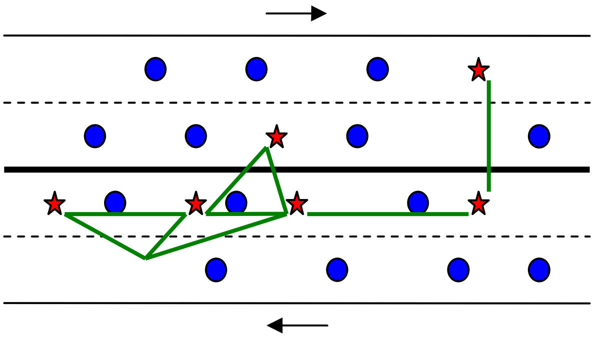


Fig. 16. Chain mobility structure.

Figure 16 to Figure 22, the dots represent vehicles that are not carrying APs, while the starts represent vehicles that are carrying APs.

Figure 16 shows the freeway type of mobility or linear structure, which is a well known chain network structure. It is common in trains' mobility. In this kind of mobility, the mobile nodes carrying APs are in random positions. The lines between the APs show one possible network topology. However, these connections depend on the distance between the nodes (area of coverage of each node), as well as the quality of the link between the APs.

The distribution of the cars carrying APs is a random event as well as the network traffic. Additionally, due to the fact that the transmission will take place hop by hop between the APs, the congestion in the APs is also a random event. It will depend on the direction in which most of the transmission takes place.

In Figure 16, the communication between the different mobile APs can take place in all directions. Therefore the network congestion is expected to be a random event. It needs to be tested in order to study the need for using fixed APs along the freeways to minimise the distance and the congestion between APs, especially during peak hours of traffic on the roads. In fact, during the peak hours, when the traffic increases, the number of APs on the roads is expected to increase as well, and therefore the topology structure will follow the shape of the roads. As it is expected when the traffic increases in freeways and highways, the topology will have a chain structure.

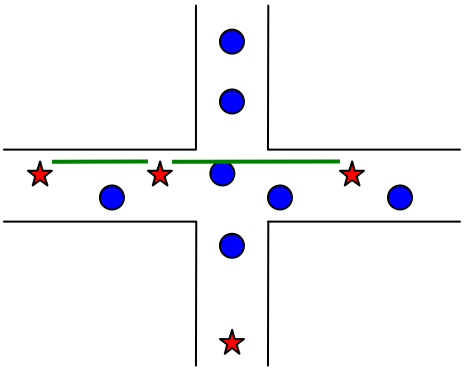


Fig. 17. Cross mobility structure.

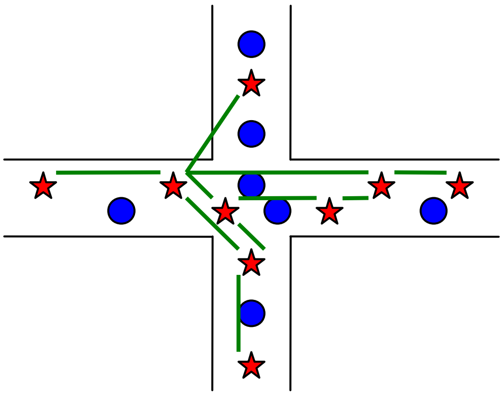


Fig. 18. Cross mobility structure with high traffic.

When the number of APs and users increases on the roads, the interference will also increase. Therefore there will be more interference over the transmission path between some of the APs and the data may not reach its destination. A mechanism to overcome with this problem is to transmit hop by hop over shorter distances between the APs until it reaches the destination.

Figure 17 shows the cross mobility structure. The green lines indicate a possible network topology for this kind of road. The topology will not follow the structure of the roads if there are not many nodes carrying APs or if those APs are too far apart. It will also not follow the road structure if the APs are all concentrated in one direction. However, when the number of APs increases the topology follows the structure of the roads. In this kind of topology (cross) structure, when the communication takes place in all directions and there are many access points, congestion is expected in the APs located in the middle. This is because most of the transmissions will tend to pass around the central point of the network topology. An example of this is given in Figure 18. Therefore, in peak traffic hours, the topology of the network can be predicted.

When the vehicular traffic increases, the velocity of the nodes usually decreases, and therefore the network topology for the mobile wireless network will also change more slowly.

Figure 19 shows the Manhattan mobility structure which is used in many cities or areas of different cities around the world. The lines connecting the APs in the figure show a possible topology in this mobility structure. This mobility structure is the result of putting many cross mobility structures

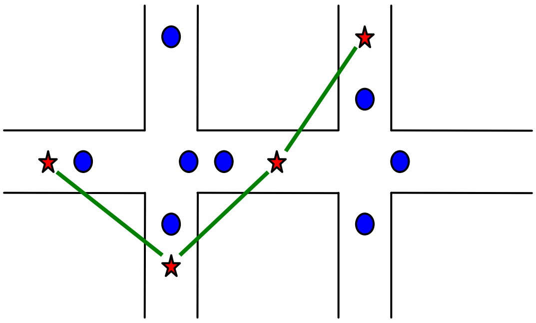


Fig. 19. Manhattan mobility structure.

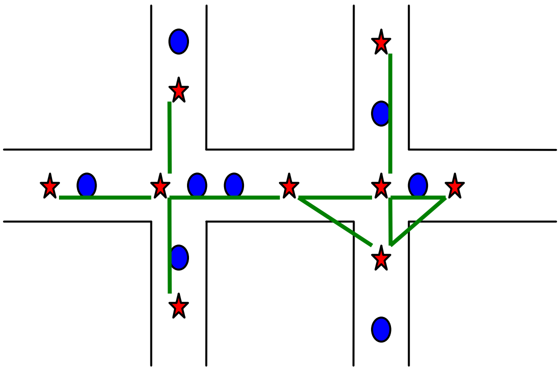


Fig. 20. Manhattan mobility structure with different topology.

together. Therefore, the congested APs are expected to be at the intersection between the roads. As can be seen from Figure 20, when the number of APs increases, the network topology resembles the Manhattan mobility structure more. In this figure, there are more APs and they are closer to each other than in the previous figure. Therefore, the mobility structure has more influence on the network topology.

Another structure is the circular mobility structure, as Figure 21. The straight lines grouping the APs show a network topology in this kind of mobility. If the number of nodes carrying APs increases, the network topology will be groups of circular topologies.

Finally the random mobility structure is shown in Figure 22. In this kind of mobility, when the traffic increases, the shape of the network topology cannot be predicted and it can take any shape. Therefore, the time for finding the network topology may increase.

V. Security of Calls

Security in VN is challenging, to guarantee public safety on the roads and to protect them from different types of security attacks; vehicular networks need efficient and suitable security architectures [20].

A list of general security requirements is mentioned in [20]–[22]. In [20], [21]. For secure VN, misbehaving nodes have to be identified and vacated to avoid disturbing the network [23] Moreover, in [2] the proposed design makes the security management in VN scalable and economical, that only RoadSide Service Units (RSSU) will have certificates which is more flexible to be handed down than certificates of vehicles because it can appear in different places. The other major advantage is that certificates can be controlled by the department of transportation in that area. Also RSSUs can offer security services such as Secure Positioning and Data Verification.

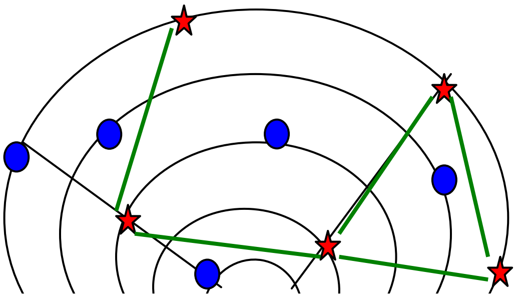


Fig. 21. Circular mobility structure.

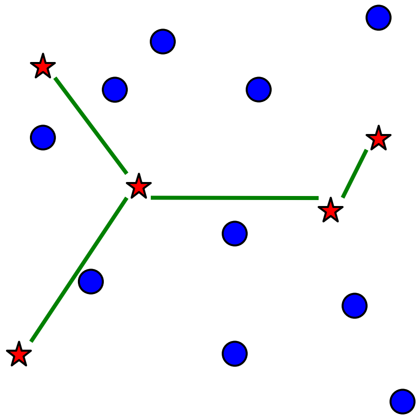


Fig. 22. Random mobility structure.

VI. Network Topology

Network topology is the physical arrangement or the spatial configuration of the network, vehicular networks will suffer from rapid changes in topology due to its dynamic characteristics [1].

A. *Topology Convergence*

The main requests for vehicular network are:

1) Create and maintain stable links for the required QoS.
2) Allocate reasonable resources to maintain user-oriented services.
3) Provide appropriate reliability.
4) Secure communication links and provide fault tolerance and self-restoration mechanism.
5) Extent to future expected network developments and growths [24].

To incorporate all these issues, the objective in topology convergence is first to:

1) To make the direction, finding table of the moving wireless network up-to-date with the sudden changes in topology.
2) Prevent and/or cut as much as possible the delays and overhead related with topology control and discovery.
3) To find the converged topology that maximizes system capacity and system throughput by minimizing management costs and interference.
4) Self-adapting the topology to achieve the required QoS and security requirements by optimizing node collaboration and economically utilizing battery power as much as possible [24], [25].

Several successive stages leading to topology convergence include:

1) Distributed Behavior Topology discovery (e.g., gateways discovery for mobile hotspots).

2) Multiple objectives optimization process.
3) Behavior/pattern matching with a known optimal topology.
4) Configuration/reconfiguration/activation [24].

In [24], an ant-based topology convergence algorithm was proposed to address the complexity and unknown nature of topology convergence in vehicular communication networks (VCNs) and to find the converged topology which maximizes system performance and guarantees additional reliable and maintainable system topology to achieve system throughput and QoS. In [25], authors proposed an adapting dynamic network topology to match changing QoS requirements in real-time wireless broadband networks based on the measurements of the received signal strength (RSCP and Ec/No) between the access points. The idea for ensuring the quality of links for specific services was done by gathering the information on the location of mobile hosts with the measured signal strengths in the links as seen by the mobile host to decide which link should be used for sending the packet towards its destination in real-time, which leads to a good match between the dynamic network topology, path satiability and the required QoS. In other words, Different topologies with different link qualities can therefore be established to provide different services with different link requirements [25].

Despite these, more research needs to be done on how fast and how spectacularly the topology can change as a function of speed and terrain. Considering the roads structures where the mobile network hosts are, the coverage range, velocity between APs and the terrain when studying the network topology of a moving broadband wireless network.

B. *Topology Prediction*

Velocity and type of mobility are the two most important aspects to consider in order of predicting the mobile wireless network (MWN) topology, where the access points (AP) are constantly moving [26].

The resulting network topology will be likely to have the form of the type of mobility structure of the roads in the area at the same time as the number of APs increases, for that reason, the topology can be predicted according to the roads segment in the different areas of the city. This gives advantage in increasing the number of APs related to the traffic on the roads. As a result, more APs points will be available to handle the traffic of the network when more services are required [26]. Topology control can be used to improve the QoS in mobile wireless networks [27]. The principle of predicting the topology of a dynamic Network by estimating the location of nodes depending on Network surrounding environment was presented in [27], where a new algorithm called Topology Convergence (TC) was proposed to estimate the nodes location then predict the topology of the dynamic network and update routing tables according to that estimation. This algorithm gives two advantages to the dynamic networks by saving the bandwidth by reducing the control packets and reducing the delay to find a path to the destination, because routes are always available by using topology prediction.

C. *Topology Control*

There are two approaches to topology management in mobile ad hoc networks: power control and clustering [8], [28]. Topology control targets the protection of the chosen topology in a wireless network by adjusting transmission power at each node such that objectives function of the transmission powers are optimized [24], [28].

The topology of a multihop wireless network is the set of communication links between node pairs used completely by a routing mechanism. Topology depends on unmanageable factors such as node mobility, weather, interference, noise, transmit power and antenna direction. Whereas significant research has been done on routing mechanisms that efficiently respond to changes in the topology due to unmanageable factors, the area of monitoring the manageable parameters in order to create the required topology has received little attention [29]. Why do we want to manage the topology? Basically, because an incorrect topology can considerably reduce the capacity, increase the end-to-end packet delay and decrease the robustness to node failures. For example, there is a danger of high end-to-end delays and network partitioning if the topology is too sparse. On other hand, if the topology is too dense, the limited spatial reuse reduces network capacity. Networks are expected to experience a significant fragmentation, resulting in degraded characteristics and disrupted connectivity if it does not employ topology control. Furthermore, transmit power control strengthens the battery life of the nodes which is an essential factor for many multihop wireless networks [29].

While dealing with network Topology, numerous factors such as interference, Robustness, delay, and throughput should be considered. Interference is a fundamental issue because it may cause collisions and subsequently packet retransmissions at the medium access control layer, which cause degrading network throughput, increasing in channel access delay and wasting the system energy [30].

Authors in [30] proposed a heuristic algorithm to determine network topologies with low interference loads to solve the minimum interference load problem. The goal is to find a network topology whose interference load is minimized under the constriction that the network is connected where at least one routing path for any pair of nodes in the Network existed. The proposed algorithm has much improved performance where the interference load is reduced.

VII. LINK STABILITY

There are different ways of analysing the reliability of a link between two APs. One method consists of considering the distance and the velocity between two APs. This can be used to estimate the quality of a link and for how long it can be used. This will mainly depend on the velocity of vehicles and the coverage range of the APs being used. Another more reliable method is by measuring the strength of the signals between APs. In this method, it is necessary that the access point or handsets can measure the quality of the signal of the nodes around them. The parameters to measure are the power and signal-to-noise ratio, which are important for determining whether there are reliable links for transmitting and providing the required services. Each service being provided for a network requires different threshold values of these parameters. For example, if the required service is a video call, it will require a stronger link than just a simple voice call. A strong link has better signal to noise ratio.

In the vehicular environment the link stability depends on the relative velocity between the vehicles and the terrain.

When the signal power at the access points is good enough to propagate the data links will be more stable but when the power drops to a small value the links become unstable. In this case link stability can be expressed as function of the received power

$$l_s(v, e_d) \rightarrow p_{rd}(l(v, e_d)) \tag{9}$$

Where l_s is the link stability, v is the relative velocity between nodes, e_d is the terrain as a dynamic factor and p_{rd} is the received power. As an example we have a scenario as shown in the Figure 23.

Where R is the route between the nodes, then

$$R_1 \Rightarrow A_1 \rightarrow A_2 \rightarrow A_4$$

$$R_2 \Rightarrow A_1 \rightarrow A_3 \rightarrow A_4$$

Where A_1, A_2, A_3, A_4 are the access points.
The capacity for each route is expressed by:

$$\begin{aligned} C_{R_1} &= B_1 \log(1 + SNR_1) = \\ &= B_1 \log\left[\left(1 + \frac{S_{12}}{N_{12}}\right)\left(1 + \frac{S_{24}}{N_{24}}\right)\right] \end{aligned} \tag{10}$$

$$\begin{aligned} C_{R_2} &= B_2 \log(1 + SNR_2) = \\ &= B_1 \log\left[\left(1 + \frac{S_{13}}{N_{13}}\right)\left(1 + \frac{S_{34}}{N_{34}}\right)\right] \end{aligned} \tag{11}$$

When the required capacity $C \cong C_{R_1}$ or $C \cong C_{R_2}$ then the link is stable, otherwise the link is unstable if this capacity cannot be achieved and the network will be fragmented. In order to propagate information between nodes in a vehicular network the lifetime of links is important. Some nodes are more stable than others in a dynamic environment because some nodes suffer from unpredictable link failures [9].

The proposed method takes into consideration the network density, transmit range and number of devices. Using the detection of the stable nodes based on heuristics method described in [9] will have an advantage for the clustering methods to elect nodes whose links are more stable to their neighbors. The objective should be reducing the re-clustering and cluster head re-election reducing message overhead and make the clustering methods more effective. More work is required on link stability including other factors like link history, geographical position, nodes direction and congestion.

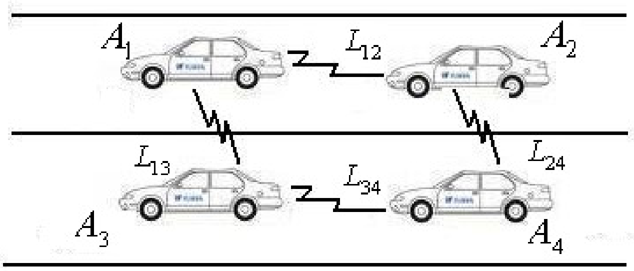


Fig. 23. Links between access points in VN.

In [31], a new model called MOPR (MOvement PRediction) was proposed; it used vehicles movement information (direction, position, and speed) prediction to estimate the stability of each link in the network and choose the most stable path from the most stable intermediate links between the source and the destination. This method improves existing unicast routing protocols by using more stable paths, which means less link failure probability during the communication.

VIII. FRAGMENTATION MANAGEMENT

A network is fragmented when the immediate path between sender and required receivers is unavailable and the massage cannot be delivered to its destination because of connectivity gap [32]. Fragmentation in VANET occurs due to the high mobility and suddenly changed topology where nodes become more unstable which gives high probability of network partitioning. Authors in [19] stated a method to multicasting messages among highly mobile hosts in ad hoc networks to help vehicles overcome fragmentation problem especially in safety application.

The proposed method maintains a list of neighbors by each vehicle to insure the vehicle forwards the message of subsistence of neighbor vehicles reachable by the broadcasted message. This helps in the detection of the connectivity gap but at the same time results in a significant overload in network. Store-carry-forward strategy mentioned in [5], [7] helps in maintaining the connectivity in case of broken links or fragmented network. In [32] fragmentation in VANET and its effect on the broadcasting process was studied. An efficient scheme was proposed which insures the propagation of massage to all vehicles with a low overhead because network needs to switch over of additional messages just in case of fragmentation. This work does not take into consideration different road topologies and changing types of nodes in VANET.

IX. CONCLUSION

ITS main goal is to make driving more safety by providing safety information using vehicular network in bad weather, congestions, accidents, and other emergence situations.

Communication through VNs can provide other services to the users onboard like internet access, and other entertainments. In this paper, we reviewed and focused on the management issues of VNs and what has been researched and studied.

According to the reviewed researches, we defined some problems within the management issues. In future work, we will focus on these concerns to solve them to manage communication through VNs [4].

REFERENCES

[1] C.-C. Hung, H. Chan, and E. H. K. Wu, “Mobility pattern aware routing for heterogeneous vehicular networks,” in *Wireless Communications and Networking Conference*, 2008, pp. 2200–2205.

[2] B. Aslam, W. Ping, and C. Zou, “An economical, deployable and secure vehicular ad hoc network,” in *Military Communications Conference*, 2008, pp. 1–7.

[3] R. Fujimoto, R. G. H. Wu, and M. Hunter, *Modeling and Simulation Tools for Emerging Telecommunication Networks Springer US*. Springer, 2006, ch. Evaluating Vehicular Networks: Analysis, Simulation, and Field Experiments Excerpt, pp. 289–308.

[4] Y. H. Ho, H. A. Hua, and K. A. Hua, “Dynamic route diversion in vehicular networks,” in *International Conference on Telecommunications*, 2008, pp. 1–8.

[5] S. Panichpapiboon and W. Pattara-Atikom, “Connectivity requirements for a self-organizing vehicular network,” in *Intelligent Vehicles Symposium*, 2008, pp. 968–972.

[6] L. Pei’en, H. Hongyu, S. Wei, L. Minglu, and W. Min-You, “Performance evaluation of vehicular DTN routing under realistic mobility models,” in *Wireless Communications and Networking Conference*, 2008, pp. 2206–2211.

[7] A. Agarwal, D. Starobinski, and T. D. C. Little, “Analytical model for message propagation in delay tolerant vehicular ad hoc networks,” in *Vehicular Technology Conference Spring*, 2008, pp. 3067–3071.

[8] N. Nikaein and C. Bonnet, “Topology management for improving routing and network performances in mobile ad hoc networks,” *Mobile Networks and Applications*, vol. 9, pp. 583–594, 2004.

[9] M. R. Brust, C. H. Ribeiro, and S. Rothkugel, “Heuristics on link sability in ad hoc networks,” in *Network Operations and Management Symposium*, 2008, pp. 738–741.

[10] K. Andersson, C. Ahlund, B. S. Gukhool, and S. Cherkaoui, “Mobility management for highly mobile users and vehicular networks in heterogeneous environments,” in *33rd IEEE Conference on Local Computer Networks*, 2008, pp. 593–599.

[11] Y. Kun, O. Shumao, C. Hsiao-Hwa, and H. Jianghua, “A multihop peer-communication protocol with fairness guarantee for IEEE 802.16-based vehicular networks,” *Transactions on Vehicular Technology*, vol. 56, pp. 3358–3370, 2007.

[12] A. H. Ho, Y. H. Ho, and K. A. Hua, “A connectionless approach to mobile ad hoc networks in street environments,” in *Intelligent Vehicles Symposium*, 2005, pp. 575–582.

[13] N. Meghanathan, “Location prediction based routing protocol for mobile ad hoc networks,” in *Global Telecommunications Conference*, 2008, pp. 1–5.

[14] E. Lawrey, “The suitability of OFDM as a modulation technique for wireless telecommunications, with a CDMA comparison,” 2001.

[15] O. Brickley, S. Chong, M. Klepal, A. Tabatabaei, and D. Pesch, “A data dissemination strategy for cooperative vehicular systems,” in *Vehicular Technology Conference Spring*, 2007, pp. 2501–2505.

[16] E. Schoch, F. Kargl, M. Weber, and T. Leinmuller, “Communication ptterns in VANETs,” *Communications Magazine*, vol. 46, pp. 119–125, 2008.

[17] P. Yanlin, Z. Abichar, and J. M. Chang, “Roadside-aided routing (rar) in vehicular networks,” in *International Conference on Communications*, 2006, pp. 3602–3607.

[18] R. Benkoczi, H. Hassanein, and S. Akl, “On the average capacity of vehicle to vehicle networks,” in *Global Telecommunications Conference*, 2007, pp. 1092–1096.

[19] L. Briesemeister and G. Hommel, “Role-based multicast in highly mobile but sparsely connected ad hoc ntworks,” in *First Annual Workshop on Mobile and Ad Hoc Networking and Computing*, 2000, pp. 45–50.

[20] P. Papadimitratos, L. Buttyan, T. Holczer, E. Schoch, J. Freudiger, M. Raya, M. Zhendong, F. Kargland, A. Kungand, and J. P. Hubaux, “Secure vehicular communication systems: Design and architecture,” *Communications Magazine*, vol. 46, pp. 100–109, 2008.

[21] P. Papadimitratos, ““On the road”–Reflections on the security of vehicular communication systems,” in *International Conference on Vehicular Electronics and Safety*, 2008, pp. 359–363.

[22] S. Eichler, “A security architecture concept for vehicular network nodes,” in *6th International Conference on Information, Communications & Signal Processing*, 2007, pp. 1–5.

[23] M. Raya, P. Papadimitratos, I. Aad, D. Jungels, and J. P. Hubaux, “Eviction of misbehaving and faulty nodes in vehicular networks,” *Journal on Selected Areas in Communications*, vol. 25, pp. 1557–1568, 2007.

[24] F. Chiang, Z. Chaczko, J. Agbinya, and R. Braun, *Computer Aided Systems Theory-EUROCAST 2007*. Springer, 2007, ch. Ant-Based Topology Convergence Algorithmsfor Resource Management in VANETs, pp. 992–1000.

[25] J. I. Agbinya and G. P. Navarrete, “Topology adaptation to services in wireless networks in motion (NEMO),” in *Third International Conference on Broadband Communications, Information Technology & Biomedical Applications*, 2008, pp. 301–310.

[26] G. P. Navarrete, J. I. Agbinya, M. Momani, and M. Akache, “Analysis of the topology for moving wireless networks,” Sydney, Austrarlia, 2007.

[27] M. Al-Hattab and J. I. Agbinnya, “Topology prediction and convergence for networks on mobile vehicles,” in *International Conference on Computer and Communication Engineering*, 2008, pp. 266–269.

[28] L. Bao and J. J. GarciaLunaAceves, “Topology management in ad hoc networks,” in *Proceedings of the 4th ACM International Symposium on Mobile Ad Hoc Networking & Computing*, 2003, pp. 129–140.

[29] R. Ramanathan and R. Rosales-Hain, “Topology control of multihop wireless networks using transmit power adjustment,” in *Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings*, vol. 2, 2000, pp. 404–413.

[30] W. Kun-da and L. Wanjiun, “Revisiting topology control for multi-hop wireless ad hoc networks,” *Transactions on Wireless Communications*, vol. 7, pp. 3498–3506, 2008.

[31] H. Menouar, M. Lenardi, and F. Filali, “Movement prediction-based routing (MOPR) concept for position-based routing in vehicular networks,” in *IEEE 66th Vehicular Technology Conference*, 2007, pp. 2101–2105.

[32] S. Khakbaz and M. Fathy, “A reliable method for disseminating safety information in vehicular ad hoc networks considering fragmentation problem,” in *The Fourth International Conference on Wireless and Mobile Communications*, 2008, pp. 25–30.