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V2V Communication in 5G Multi-RATs and VANet Clustering Model from Localization Approaches

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Abstract

Vehicular Ad Hoc Network (VANet) enables Vehicle to Vehicle (V2V) communication to exchange safety and non-safety information. VANet is a well-defined and self-organized network topology with no fixed infrastructure. V2V communication was allocated the Dedicated Short Range Communication (DSRC) spectrum by FCC to enhance services in Intelligent Transportation Systems (ITS). Advances in mobile and wireless communication led to applications development, for instance Device to Device communication (D2D) for 4G is found useful for VANets due to its proximity services. Furthermore, 5G promises high data rate, reduced latency and extension of radio spectrum. In this paper; we study the feasibility to multiplex existing and new opportunistic radio spectrum, we focus on proximity for node discovery and clustering through localization. The parallel analysis of unlicensed DSRC spectrum and the unlicensed band of mmW for 5G are the main contributions to conduct this work. Some useful algorithms are presented as well.

Keywords: *VANet, DSRC, 4G, Localization, Clustering, 5G.*

1. Introduction

T Mobile Ad Hoc Network (MANet) is an infrastructure-less network where mobile nodes exchange data in a well-defined topology. In VANet, data is shared among vehicle during mobility at high speed[1],[2],[3]. VANet is one the practical application of MANet which is also a subclass of Wireless Ad Hoc Network (WANet) [4]. In V2Vcommunication, a mobile network is established between moving nodes or vehicles.

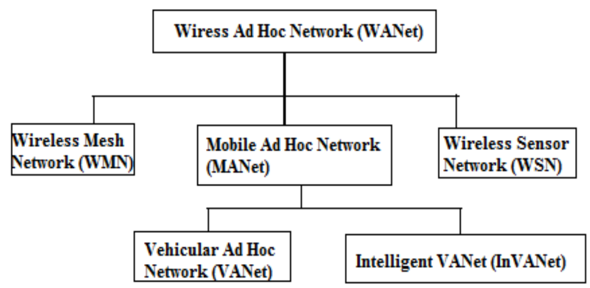

Fig.1 Classification of Ad Hoc Networks.

The IEEE 1609 -DSRC Working Group is in charge of developing standards for Wireless Access in Vehicular Environments (WAVE), communication is based on IEEE 802.11p which is an amendment to IEEE 802.11 standard in order to support communication in dynamic vehicular environments. IEEE 802.11p standardizes the communication aspects related to physical (PHY) and Media Access Control (MAC) layers [5] as shown in Fig.2.

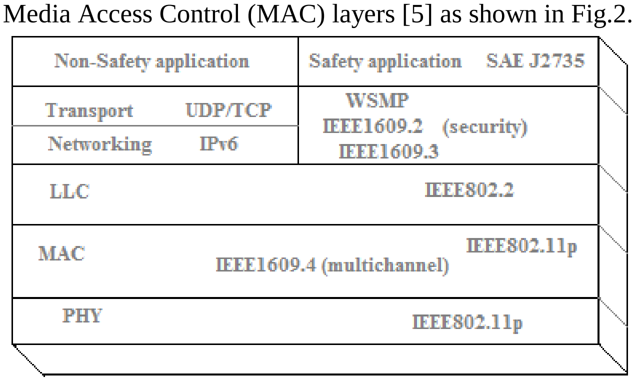

Fig.2 WAVE protocol stack and its associated standards

The spectrum allocated to DSRC (70MHz band of seven channels; one control and six services with 10MHz each) suffers from capacity due to increase in number of vehicles [2],[6]. It was suggested and accepted that *white band* or

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underutilized spectrum of Primary Users (PU) can be shared with Secondary Users (SU) without causing harmful interference on the primary users and VANets can benefit from the same [2],[3].

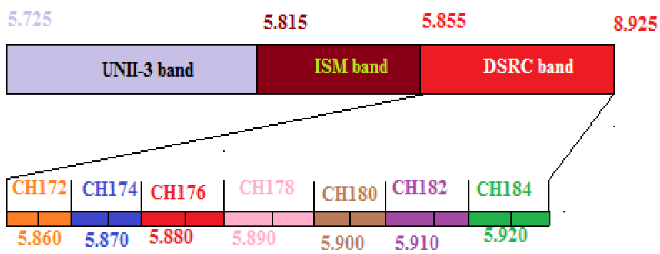

Fig.3 DSRC band allocated to V2V (all frequencies in GHZ)

A mobile network of moving nodes or vehicle makes every participating vehicle into a wireless router or node, allowing vehicles within approximately 100 to 300 meters of each other to connect and create a network on a wide range.

As vehicles fall out of the signal range they drop out of the network, strongly connected vehicles make a *cluster* to start a group communication.

Basically, V2V communication requires an On Board Unit (OBU) which serves as radio communication. Another alternative to make the system sustainable is to communicate through the fixed infrastructures which require a Road Side Unit (RSU) as an access point deployed in some locations on the road or existing infrastructures such as 3G and 4G [1].

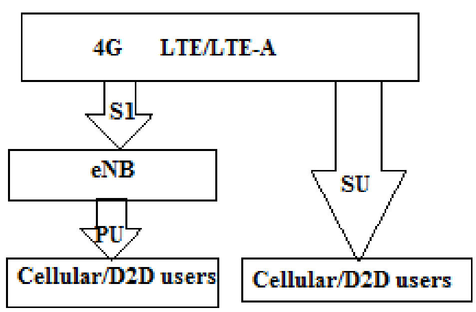

Fig.4 D2D scenario in 4G system (S1: interface between core network and eNB)

Vehicles should exchange minor and urgent information for safety application such as breaking, lane change, overtaking and others. Traffic control keeps track on road condition and share information to ensure emergency as well as non-safety applications [1].

The 4G Long Term Evolution (LTE) and LTE-Advanced (LTE-A) has enabled a promising direct communication between devices in vicinity by offloading eNB [1]. The 4G supports *high mobility* of nodes with speed up to 350 Km/h that can be applied for V2V communication [7],[8]. This will enhance the ITS since D2D communication will turn into V2V communication and difference radio access could be used in multiplexed and dynamic mode. Furthermore, 5G will improve considerably the applications of V2V communication due to the fact that it promises to offer high data rate and reduced latency [9]. VANets is one the most beneficial application due to high bandwidth available for unlicensed spectrum in millimeter wave (mmW) band which Vehicles would operate in [9].

5G is a complementary network which consists of a scalable Radio Access Technologies (RATs) in order to achieve the awaited high data rate [10] , the use of higher frequencies will be adopted, the corresponding wavelength will be in the range of millimeters (one millimeter to ten millimeters) [10] and will use mmW band ranging from 30GHz to 300GHz [11],[12],[13]. To clearly understand V2V communication for the above described current and next generations of technology; a network of vehicles shall be created in a grouped Ad Hoc to make *Clusters*, each vehicle will communicate to others in same cluster or to another cluster depending on the topology drawn [1].

For self-grouping into clusters, vehicles need to know their locations and share with other to know which network they belong to [1].

In 4G, D2D communication requires discovery of the devices for proximity condition and interference free in the primary network. Therefore, an ad Hoc network is established without involving eNB and communication is done in a secondary network. Devices have to discover each other and directly communicate with each other with minimum involvement of the network [8].

Fig.5 D2D communication scenario in 4G

The results of the above scenario are to reduce the network congestion, extended battery life, minimum spectrum utilization and enhancing the efficiency. Thus localization of the device is crucial and the distance is the most parameter to deal with.

2. System model

A network of vehicles in ITS creates a VANet with distance dependency. D2D in 4G follows proximity condition based on the distance. Thus, V2V and D2V are similar technologies which take distance as main parameter. Additionally, ITS has a dedicated spectrum DSRC while in D2D operates as secondary network and must satisfy interference and maximum allowable transmission range that is related to the power constraint [1]. The relationship between the distance and the power is indicated by the Received signal Strength Indicator (RSSI);

$$RSSI = -(10n\log_{10}(d) + K) \quad (1)$$

With K the RSSI value at reference point, n path loss exponent and d the distance between the transmitting and receiving devices. Since transmitted and received powers are the deterministic factors, the distance between two devices (vehicles in our context) is expressed as;

$$P_{Rx} = c\frac{P_{Tx}}{d^n} \quad (2)$$

$$d = \sqrt[n]{\frac{cP_{Tx}}{P_{Rx}}} \quad (3)$$

Where c is the gain of the transmit antenna, P_{Tx} is the transmitted power, P_{Rx} the received power d the distance and n the poth loss exponent.

Another way of distance calculation is to use the positions of objects and apply the simple Euclidian distance; this is the concept of localization.

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (4)$$

Different localization techniques summarizes the distance based localization where the distance between nodes are measured, angle based localization where mobile nodes can measure the angles like angle of arrival (AoA) to the anchor nodes with respect to some origin while RSSI assumes that mobile can only measure the signal power from the base stations as its location; time of arrival (ToA), time difference of arrival (TDoA) [14],[15],[16], [17].

Clustering in V2V communication follows distance calculation from shared positions which may be obtained from the above mentioned localization techniques. Most of positioning techniques uses Global Positioning System (GPS) which provide the position of an object by applying Triangulation and Trilateration methods.

Let us compute the positions of fixed point with one taken at the origin,

$$\begin{cases} d_1{}^2 = x^2 + y^2 \\ d_2{}^2 = (x-p)^2 + y^2 \end{cases} \quad (5)$$

The true position is given by

$$\begin{cases} x = \dfrac{d_1{}^2 - d_2{}^2 - p^2}{2p} \\ y = \pm\sqrt{d_1{}^2 - \left(\dfrac{d_1{}^2 - d_2{}^2 - p^2}{2p}\right)^2} \end{cases} \quad (6)$$

For trilateration, the object with a position P is unknown and its position can be found using the known distances and positions of any two points. Two approaches can be used: angles and distances as discussed below.

Analysis;

Known quantities are a(X,Y,Ø), b(X,Y,θ) as well as L.

Unknown quantities are P(X,Y) and d.

From geometry of angles (Thales);

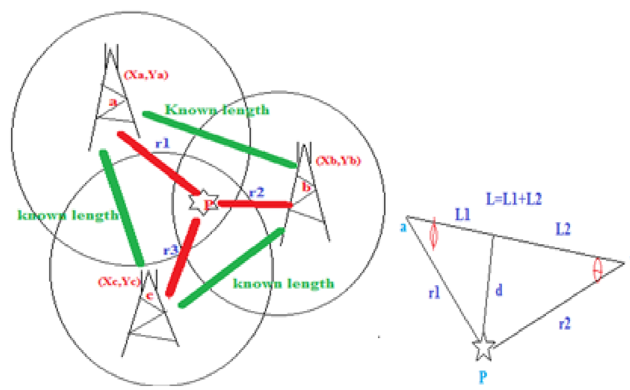

Fig 6 Trilateration and trilateration for distance calculation

$$\begin{cases} \sin\theta = \dfrac{r2}{L2} \\ \cos\theta = \dfrac{r2}{d} \\ \tan\theta = \dfrac{d}{L2} \end{cases} \text{ and } \begin{cases} \sin\Phi = \dfrac{r1}{L1} \\ \cos\Phi = \dfrac{r1}{d} \\ \tan\Phi = \dfrac{d}{L1} \end{cases} \quad (7)$$

$$L = \frac{d}{\tan\phi} + \frac{d}{\tan\theta} \quad (8)$$

$$d = L\left(\frac{\tan\phi\tan\theta}{\tan\phi + \tan\theta}\right) \quad (9)$$

$$\begin{cases} \left(X_P - X_a\right)^2 + \left(Y_P - Y_a\right)^2 = r_1^2 \\ or \\ \left(X_P - X_b\right)^2 + \left(Y_P - Y_b\right)^2 = r_2^2 \end{cases} \quad (10)$$

3. Proposed system

3.1 Simple Clustering algorithm

In this paper, we propose a model of distance based cluster formation, some clustering algorithms are surveyed; K-means which is simplest and unsupervised learning algorithm that solve well known clustering problem. For a given *K* (number of clusters), vehicles are partitioned into *K* non empty subsets and centroids (mean point) are identified for each subset [18]. Each point is assigned to a specific cluster with minimum distance to the centroid.

Generally, the following algorithm is followed while considering the distance between neighboring vehicles in order to group them.

- Initialize
- Calculate Euclidian distance for each neighbor
- Apply proximity conditions
- Update neighbor status
- Make group according to proximity conditions
- End the process

From the algorithm, a random distribution of vehicles located at different positions in a known area, a conditional range between any two vehicles is set to be the maximum threshold. All vehicles satisfying the condition shall belong to the same clusters, see Fig 7.

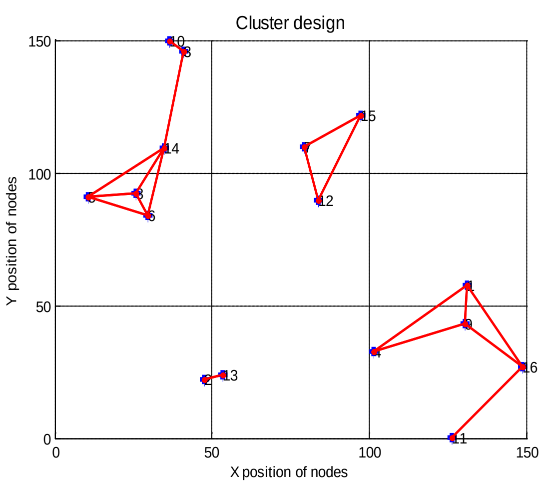

Fig 7 Cluster formation based on distance between nodes

16 nodes are randomly distributed on an area of (150,150), the range is 40. This network shows 4 clusters which vary according to the design conditions. In this work we analyze networks of vehicles for different vehicular environment that should be carefully treated during implementation. Networking of vehicles requires grouping them in set of common parameters in order to keep the network alive for longer duration (less dynamic network). This is because vehicles communicate while on high mobility topology. For an efficient communication; a group of vehicles called "cluster" will be defined and members will communicate among themselves. For a big network; cluster head will be elected and shall take responsibility of inter-cluster communication called internetworking. Parameters like distance between vehicles, speed of vehicles and direction are most important in the design. These parameters can be obtained using GPS.

3.2 V2V communication scenario for 4G LTE-A

Vehicular environment is based on a high dynamic topology; distance between vehicles is a critical parameter during transmission and efficient communication. This work takes reference of proximity analysis for D2D where vehicles are distributed exponentially on a specified road length.

The expression of the distance with reference to the power constraints is evaluated in different channel environment;

$$d_{DD}{}^{\alpha} = \frac{(k-1)d^{\alpha}{}_{BD}h^{-1}{}_{BD}h_{DD}}{\beta_D\left(\beta_B d^{-\alpha}{}_{CD}d^{\alpha}{}_{BC}h^{-1}{}_{BC}h_{CD}+1\right)} \quad (11)$$

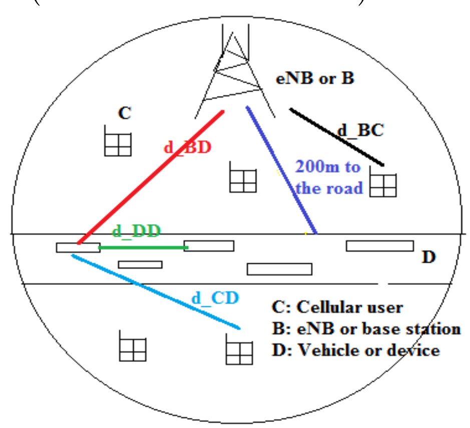

Fig 8 D2D scenario in 4G LTE-A

The eNB has control of V2V network but doesn't involve in communication if all conditions are satisfied because D2D concept is to offloading eNB [19]. Thus creating internetworking between primary and secondary network for V2V operating in LTE-A , one base station called eNB (labeled **B**) is supposed to cover an area of say 500m [19], cellular users (labeled **C**) are randomly distributed all over the area and their distance to eNB is labeled d_{BC}. Similarly a road is passing in the cell coverage at 200m, vehicles (here labeled **D**) are distributed in the road and the distance of the scenario are labeled as follows; d_{DD}, d_{CD}, d_{BD} are distance between two vehicles, distance between cellular user and device, eNB and device respectively whereas β_B, β_D and k are 10dB, 5dB and 3dB respectively are taken as interference threshold. Let α=2.

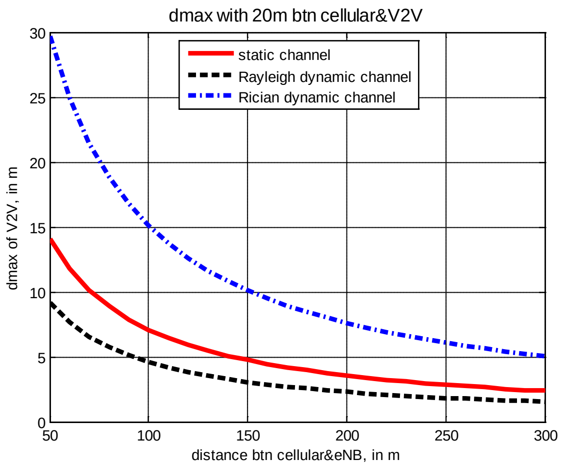

Fig 9 Transmission range of V2V for different channels when primary user is close

For static, Rayleigh and Rician channels; we observe the impact of primary users to secondary users for accessing the resource or spectrum; when cellular users are nearby V2V network, the transmission range is small and V2V network requires vehicles to be close for communication to take place. It is observed that Rayleigh channel is the worst and Rician the best while for cellular users far from V2V network; it is observed that the transmission range between any two vehicles is increased because the interference from primary users is less. Similarly, Rician is the best channel condition

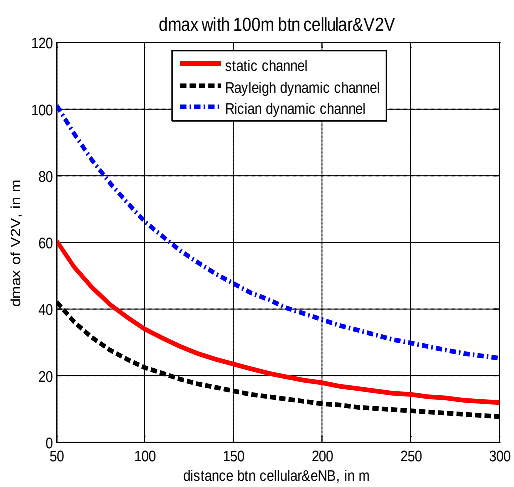

Fig 10 Transmission range of V2V for different channels when primary user is far

This analyses the impact of distance when two networks are operating in one core system sharing same resources. This work is limited to the transmission range for secondary network according to the position of the primary network. Since 4G is a completely a licensed spectrum, it gives an insight on the next generation of technology 5G that is supposed to operate in higher frequencies through which, some frequency will be free or unlicensed band.
We propose that V2V shall find its slot, for instance 60GHz is unlicensed band ranging from 59GHz to 66GHz [20] with a bandwidth of 7GHz. The band is enough to offer high data rate and low latency as the primary requirements of V2V networks in order to exchange safety and emergency information among vehicles.
By embedding all existing technologies together and accomplishing the system by emerging 5G technologies; V2V communication would utilize salable bands. If all vehicles are equipped with a radio technology that holds the access which covers all radio frequencies until mmW, then the communication among vehicles would be defined only by their topologies and environments. By combining Multi RATs, and implementing Heterogeneous Networks (HetNet) as well as scalable RATs of the awaited 5G, VANets can become successful and infotainment would be entertained.

The structure of 5G HetNet proposed in this work shows that 5G can accommodate all existing networks and add values in terms of spectrum, many improvement are under development which are beyond the scope of this work but make part of the future directions of our research. Those include MIMO, massive MIMO as well as Visible Light Communication (VLC).

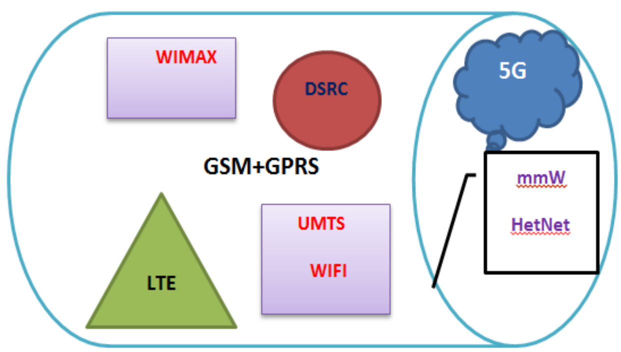

Fig 10 HetNet structure of 5G

4. Conclusions

This work presented a comprehensive study conducted in the area of Ad Hoc technology with a focus on VANets as a practical application as well as important sector which needs a serious study before any practical implementation because of its applications as well as requirements. It was reported that vehicles exchange information while moving at different speeds and the need for location of each participating vehicle was reported. For a better communication and efficient resource allocation, vehicles had to be divided into clusters as reported in this work. Furthermore, the observation has shown that the spectrum allocated to V2V communication is not enough anymore and various researches demonstrated that moving forward is the only key to enhance the services provided in VANets in order to satisfy the required applications. The development and improvement of next generation of technology have shown that 5G can help the so stated enhancement of VANet and V2V communication and develop the best ITS by adopting all the features of 5G as complement to all existing technologies. The advanced D2D communication, use of unlicensed spectrum in mmW with a wide bandwidth will enhance the data rate and reduced latency as well as efficiency required in the application ITS.

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