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Modeling of Cognitive Radio for Vehicular ad-hoc Sensor Network Using Graph Theory Concepts

*Reshma C R[1], Dr. ArunKumar B R[2]
[1]*Research Scholar, VTU Research Centre andAsst.Professor, Department of MCA, BMS Institute of Technology& Management, Bangalore, India*
[2] *Research Supervisor, VTU Research Centre and Professor & Head, Department of MCA, BMS Institute of Technology& Management, Bangalore, India*
Corresponding Author: Reshma C R

Abstract: *Spectrum scarcity is a common yet significant issue in any kind of wireless networks, To maximize the utilization of the available channels the cognitive Radio technology could be adopted in Vehicularad hoc networks(VANETs) which is a subclass of Mobile Ad Hoc Networks. The dynamic network topology in VANET can be modelled by applying the graph theory concepts such as Unit Disk Graph and Gabriel graph. This paper is a novel work by modeling the Vehicular Ad Hoc networks which uses Sensor nodes with Cognitive Radio Technology. The wireless sensor nodes are deployed on the RSU; these nodes in turn will form the network topology to communicate with the other vehicles. The communication in VANET also depends on the vehicle arrival pattern for which the Poisson distribution is applied inCognitive Radio-Vehicular Ad-hoc Sensor Network (CR-VASNET). The CR-VASNET ensures the utilization of unlicensed spectrum for effective communication in VASNET.*

Keywords: *CR-VASNET, Spectrum allocation, Gabriel Graph, Unit disk graph, V2V, V2I*

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I. INTRODUCTION

For improving the safe transportation system, an infrastructure should be provided in such a way that it is possible to communicate between the vehicles about the collision, monitor the traffic pattern and safety. This is possible through the vehicular ad-hoc networks (VANET). A vehicular ad-hoc network is defined on the set of moving vehicles on the road. A vehicle communication can be vehicles to infrastructure or vehicle to vehicle communication. Figure 1 shows the taxonomy of vehicular communication. The cognitive radio is an emerging technology for detecting the unused spectrum either in licensed band or unlicensed band. By using cognitive radio the underused spectrum are effectively utilized.The sensorsare available in the vehicles which can communicate to the road side unit. The spectrum can be managed by using the functionalities of cognitive radio network Spectrum sensing, spectrum management, spectrum decision and spectrum mobility[1]. These functionalities play vital role for effective utilization of the spectrum. To address the mobility issues in the network the graph theory concept is used.

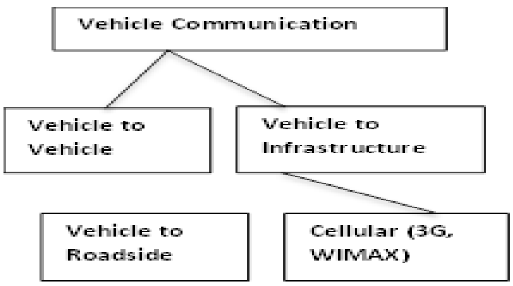

Figure1: Taxonomy of Vehicle

In this paper section 2 describes the architecture of CR-VASNET, section 3 describes graph theory concepts for modeling the CR-VASNET, Section 5 describes the Doppler effect for VASNET, section 6 is Issues of CR-VASNET, section 7 is conclusion about the paper.

II. ARCHITECTURE OF CR-VASNET

The IEEE 802.11p standard supports different cellular technology (2G/3G/4G) at high speed 200 Km/h in 5.9Ghz Band. The Standard architecture is shown in Figure 2:

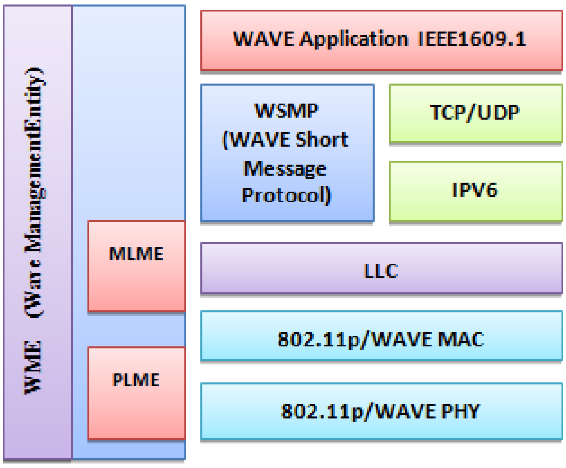

Figure 2: Architecture of CR-VASNET

2.1 Protocol of Cognitive Radio Network

The CR consists of three functionalities in layered architectures such as PHY,MAC and Network layer as shown in Figure 3:

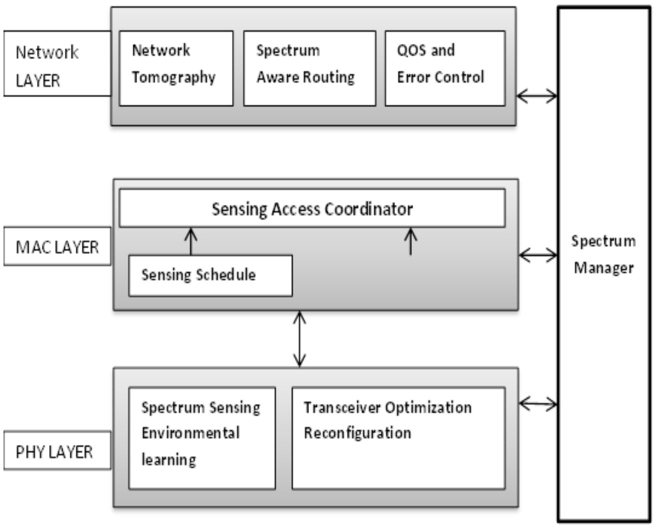

Figure 3: Functions of PHY, MAC and Network layer

In the above figure, the physical layer enables the CR users to identify the spectrum holes. Spectrum access can be performed through the transceiver optimization. The spectrum sensing is scheduled and the spectrum aware MAC controls the identified spectrum holes. In the network layer there are three functions that is carried out network tomography, routing and error control to achieve good QoS services. Cross-layer design ensures the quality of services and effective dynamic access for the spectrum[6].

III. GRAPH THEORY FOR MODELING

A graph is a geometrical representation of vertices and edges. The vehicle can communicate with another vehicle or to the roadside unit through the sensor nodes that are available in the vehicle to sense the nearest vehicle or the RSU. Consider let G1 = (V, E) where V is a set of Vehicles and E be the set of Sensors that are communicating to the vehicles in V2V. Consider a Graph G2 = (V1,V2,E) where V1 = {set of Vehicles} and V2={Set of RSU} and E be the edge connecting from RSU to Vehicles. The Graph G2 indicates the Vehicle to infrastructure where V1 and V2 forms a unit disk graph the spectrum is sensed using different sensing techniques, and the spectrum is allocated for the VASNET. The distance between the vehicle to vehicle and vehicle to infrastructure is estimated using the Euclidean distance. By Gabriel graph the nearest point for communication is established. The connectivity exists only if there are vehicle which falls in the same cluster. The Graph theory concepts are applied for organizing the sensor nodes dynamically.

The topology of vehicles is formed to communicate with each other. Since the vehicles are not stationary depending on the distance between the vehicles the network topology is formed which are dynamic in nature. The cognitive radio identifies the unused spectrum through spectrum sensing and allocates the bandwidth for vehicular communication. The sensor nodes at the road side unit identify the moving vehicles and connect to the vehicle for communication. Thegraphsunit disk graph and Gabriel graphare introduced for framing the network topology.

3.1 Unit Disk Graph

A unit disk graph is the intersection graph in a given plane. Consider n be the equal sized circles; these circles intersect with n-vertices. The unit disk graph is efficient graph for geometrical computation model. The unit disk graph can be used along with the graph coloring [3]. The chromatic number indicates the number of colors that are used to color the nodes to study the behavior of the nodes. The nodes which are able to detect the vehicle are colored to indicate that vehicle can communicate with other vehicle, so when the next adjacent are determined then the node is colored with the other color to differentiate that vehicles are able to communicate with each other and with the road side unit. Each circle indicates one unit which can have n-number of vehicles. These circles can be called as clusters. The vehicles can communicate with the same cluster or with the different clusters which depends on the distance between the vehicles**.**

3.2 Gabriel Graph

The Gabriel graph of set S of points in the Euclidean plane expresses one notion of proximity or nearness of these points. This Graph identifies nearest unused spectrum by using sensing techniques. If the spectrum is not utilized by PU then the spectrum is shared with the SU by ensuring there is no interferences caused by the PU. This available spectrum is utilized for VASNET.

IV. MODELING OF VASNET

The VASNET is self-organizing networks which are comprised of sensor nodes [2]. These nodes are organized based on the graph theory concepts. When applied Unit disk Graph the distance between the RSU and the Vehicles is calculated by using Euclidean distance. The distance is a factor which is considered for a sensor to communicate between the vehicles or vehicle to the infrastructure. The size of unit-disk depends on the number of vehicles entering to the VASNET infrastructure. If the number of vehicles entering into the infrastructure is more than the limit size, then the energy of the sensor node is decreased and interference occurs during the overlap between the primary users and secondary users. At this stage the clusters of Sensor nodes can be formed, where each cluster has a cluster head (CH). The CH of one cluster can sense the other cluster through the Gabriel graph. As and when the vehicles are moving out of the infrastructure the communication between the vehicles are interrupted.

4.1 Rate of arrival of vehicles

The vehicles entering into the VASNET infrastructure is discrete distribution. The Channel is allocated only during the movement of vehicles in the CR-VASNET infrastructure. The rate of arrival is measured in terms of Poisson process. The probability of observing the vehicles entering into the infrastructure is given by the equation 1

P= $e - lambda \, {}^{lambda\ K}_{k!}$ (1)

Lambda=event rate

K=observing eventwhich takes the value 0, 1, 2, 3….

To avoid the overlapping the arrival rate of the vehicles has to be determined. Since the bandwidth is limited the available bandwidth has or the unused bandwidth is determined by using the concept of spectrum sensing. Then the unused spectrum is allocated to vehicular communication. The mobility of the vehicles affects the network topology, to address this issue the rate of arrival of each vehicle in each cluster has to be determined. Here every vehicle is considered as a sensor node which should determine the neighbor node. The neighbor node is determined using the connectivity of each node through Gabriel graph. If the neighbor node is determined then the connectivity of node is possible by defining the edge from the point V1 (vehicle) to (vehicle) V2. If the vehicle is available in the different cluster then the intersection of cluster is determined through the unit disk graph.

4.2 Constraint to Define VASNET in Discrete Distribution

Some assumption are considered to establish the connectivity among the vehicles such as number of vehicles, number of RSU and number of unit disk circles that are framed. The vehicle should be equipped with the sensor devices and should be able to detect the nearby vehicle and connect to that vehicle. To establish the connection from RSU to vehicle:

H0: $\alpha >=1$

H1: $\alpha < 1$

H0 is a null hypothesis which indicates that can be accepted if significant value is 0.05% and number of RSU =1 and vehicle=1. Otherwise if RSU is not able to connect to vehicle then the null hypothesis is rejected. The alternate hypothesis H1 is accepted.

4.3 Euclidean Distance and Graph Theory

Euclidean Distance is applied to find the distance between the V2V and V2I, i.e. through the distance the sensor nodes will be able organize the node by itself. The Euclidean distance formula is determined in the plane as given in the equation 2:

Distance(x,y), (a,b) $=\sqrt{(x-a)^2+(y-b)^2}$ (2)

If the distance is minimum then the vehicle is in same unit disk. If the vehicle is in other disk, then it connects through the CH by defining the intersection between the clusters. Figure 6 shows the Euclidean Distance chart. As the distance between the point x and a, y and b increases the distance also increases in turn which distracts in determining the neighbor point and raises the connectivity issue during the sensing of node.

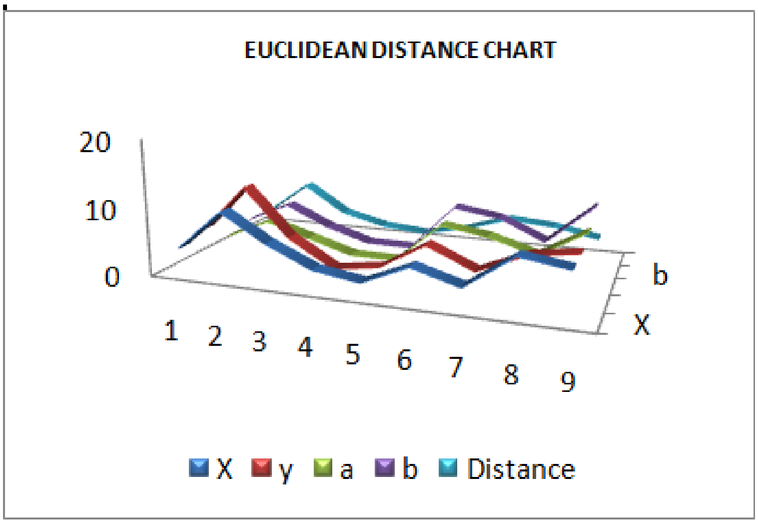

Figure6: Distance between two points.

4.3.1 Dynamic Euclidean Distance

The distance between two points in a Euclidean space is given by equation 3:

d= |x-y|$=\sqrt{\sum_{i=1}^{n}|xi-yi|^2}$(3)

The above equation is used to calculate the distance between the vehicles in the same cluster. To ensure the connectivity the shortest distance between the vehicles in the same cluster and between the clusters can be calculated using the equation 4:

d (x, y) $=\int_0^T|\gamma(t)|\,\gamma(t)dt$ (4)

where$\gamma(t)$ is path to identify the different clusters in the infrastructure. Once the shortest distance is determined, vehicle can communicate each other. To ensure the QoS in terms of connectivity the unit disk graph is used. The movementof vehicleson the road depends on the time constant. Consider the vehicles as v, at a particular instance of time t: the EIR (Euclidean Intelligent Radio) algorithm is given below:

Step 1: Sense the spectrum for allocation the channel for communication.

Step 2: Determine the number of vehicles in the infrastructure.

Step3: Apply Clustering to group the vehicles in different cluster depending on the Euclidean distance.

Step 4: Determine the shortest distance between the infrastructures and the vehicle. Apply graph theory i.e. Unit disk graph and Gabriel graph to ease the communication by forming network topology.

Step 5: Establish the communication channel by sensing the nearest vehicle to the infrastructure at the time t with thevehicle arrival rateλPoisson distribution.

Step 6: If the number of vehicles n<1 then , the channel is free at the time t. Available channel can be utilized for other application like mobile communication.

Step 7: The QoS depends on the distance between the vehicle and by applying Doppler Effect, the effective communication of moving vehicles can be determined.
Step8: The Communication is completed when there are no further vehicles are entering into the infrastructure.

V. DOPPLER EFFECT IN CR-VASNET

The change in the frequency for a moving vehicle with relative to its source is called the Doppler Effect. In CR-VASNET the Vehicle can communicate through the sensors and to the RSU depending on the velocity of each vehicle. When the vehicle is moving away from the RSU the Sensor losses its ability to communicate to the vehicle. Then the allocated channel will be idle in other words the channel will not be used for communication as the strength of signal reduces, until the other vehicles enters into the infrastructure. If the channel is allocated from the primary users (PU), then when the CR-VASNET doesn't use the channel the allocated channel can be used by PU. In other words the allocated channel can be shared to the secondary user (SU) while PU is not utilizing the channel [5].

The Doppler Effect is given by equation 5

$$f= ((c+ v_r)/ (c + v_s))\, f_0 \qquad (5)$$

where,
f=channel bandwidth to be allocated
c=Medium of Communication i.e Energy of sensor node
Vr=Velocity of the vehicle
Vs=Energy of Senor node at RSU or speed of the other vehicle
f_0 =Utilization of available bandwidth

The allocated channel is inversely proportional to the speed of the every vehicle in the unit disk; if the vehicle is moving from the unit disk then the channel will be idle if no other vehicles are there in unit disk. The channel will be maximum utilized only when there is at least two or more vehicle are there in unit disk graph to self-organize the sensor node for communication. To ensure that channel is better utilized the RSU should communicate to vehicle or V2V communication should be carried.

VI. ISSUES OF CR-VASNET

There are some challenges in CR-VASNET.
6.1Interference: This is caused due to the overlapping of PU and SU raising the demand for the usage of the channel. And if the intersection of small circles in unit disk are trying to communicate with the same RSU depending on their distance interference is caused [4].
6.2 Mobility: The speed of the vehicle raises the disputes in organizing the nodes within the clusters. The CH has to sense the neighbor node and identify the speed of the vehicle. Similarly the spectrum mobility is caused due to different channel bandwidth that is available at any instance of time.
6.3 Network Security: The communication between the vehicles should be secured by developing the cross-layer architecture for CR-VASNET it can ensure the security at the physical layer itself.
6.4 Safe transportation: The VASNET can communicate with the other vehicle if there are any accidents, traffic jam etc to be alert. If there the vehicle is changing the vehicle RSU will indicate the same to the drivers.

VII. CONCLUSIONS

This paper gives an overview of CR-VASNET through for VANET; the underutilized spectrum is used for the vehicular communication by using the cognitive sensor nodes. The reliable communication is established using the graph theory concepts. The problem is modeled using Poisson distribution to determine the speed of the vehicle and to communicate to the vehicle from the RSU.There are various challengesto address and can be analysedusing simulation.

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ABOUT THE AUTHORS

Reshma C Ris Assistant Professor and Research Scholar, VTU Research Centre in the Department of MCA at BMS Institute of Technology& Management, Bangalore, India. She is pursuing Ph.D. degree from VTU, Belagavi. Her research interests include Cognitive Radio Networks, wireless Technologies.She has published 2 research papers in International Journals.

- **Dr. ARUNKUMAR B.R.,** MCA, M.Phil (CS), M.Tech (CS&E),PGDIPR[NLSIU], awarded Ph.D (CS) from dept. of Computer Science, Dravidian University [A.P. Govt.], Kuppam, Professor and Head of the department, Master of Computer Applications, BMS Institute of Technology& Management, Bangalore, Karnataka, India, worked as Member BOS, VTU,BOE,Bangalore University 2015-16 onwards, worked as chairman BOE, KSOU,Mysore in 2009-10 for MCA and IMCA programmes, has published nearly 35+ research papers in National/International Journals and 20+ papers in National/International Conferences including IEEE international conferences. To his credit 5 candidates have earned their M.Phil (CS) degree and 5 candidates are pursuing their Ph.Dprogramme in computer Science/Applications. Dr.Arunkumar B R has got nearly 18 years of teaching experience published several papers in his area of research namely: Data Mining, Data Analytics and Visualization, Wireless ad hoc networks, Computer Networks and Security, Cloud Computing, IPR & Cyber laws and Software Engineering and authored a book titled "Application of Graph Theory Concepts to MANET Cross Layer Multicasting" published by Lambert Academic Publishing, Germany in May 2017.

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