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# Spectrum Sensing techniques for Cognitive Vehicular Networks

**K Jyostna[1], Dr. B N Bhandari[2]**

Assistant Professor, Department of Electronics and Communication Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India[1]

Professor, Department of Electronics and Communication Engineering, JNTU College of Engineering, Hyderabad, India[2]

**Abstract**: With the growing number of vehicles, millions of people are killed in road accidents every year around the globe. Also, traffic congestion and air pollution has led to poor quality of life. This has brought in the focus to improve road safety and traffic efficiency. Vehicular Adhoc Network also referred to as VANET is a vital application of Intelligent Transportation System (ITS) with enormous societal impact. Cooperative communication among the vehicles can make the driving experience safer and comfortable. But the major challenge for the effective deployment of Vehicular networks is the bandwidth allocated for VANET by Federal Communication Commission (FCC) gets insufficient during high traffic density scenarios which affects the transmission of safety messages. Cognitive Radio technology integrated with Vehicular Networks extends the spectral efficiency with Opportunistic Spectrum Access (OSA) and can improve the communications in emergency situations. Leasing additional spectrum outside of the Dedicated Short-Range Communications (DSRC) band can improve the performance of vehicular networks. This survey paper sheds light on the latest advancements that took place in Cognitive Vehicular Networks as well as current research challenges.

**Keywords:** Cognitive Radio, Vehicular Adhoc Network (VANET), Opportunistic Spectrum Access (OSA), Dedicated Short-Range Communications (DSRC).

## I. INTRODUCTION

Spectral efficiency is significantly important as wireless communication systems are providing high performance services and accommodating a greater number of users. Spectrum shortage and less consumption of accessible spectrum have been noted as problems that can be solved by the CR technology. VANET is an exciting research and application area motivated by the development of ITS and Wireless Access in Vehicular Environment (WAVE) standard[1-2]. VANET allows two types of communication i.e., communication among vehicles(V2V) and vehicles communication with road-side infrastructure(V2I) to support safety and non-safety applications as shown in Figure 1. The evolution of V2V and V2I motivated the amendment to IEEE 802.11 standard. The IEEE 802.11p (DSRC) and IEEE 1609 facilitates the exchange of information between high-speed vehicles and the road-side infrastructure. The Federal Communication Commission (FCC) has allocated 75 MHz of bandwidth in the 5.9GHz (5.855 – 5.925) licensed band to support vehicular communications. The spectrum allocated for VANET communications is divided to one control channel and six service channels each of 10MHz bandwidth used for exchanging control, safety and non-safety messages. However, this bandwidth gets congested with various messages from the vehicles during peak traffic density hours. More spectrum resource is an effective way to solve transmission congestion. Hence, CR technology is integrated with VANET(CVN) to address the spectrum scarcity problem.

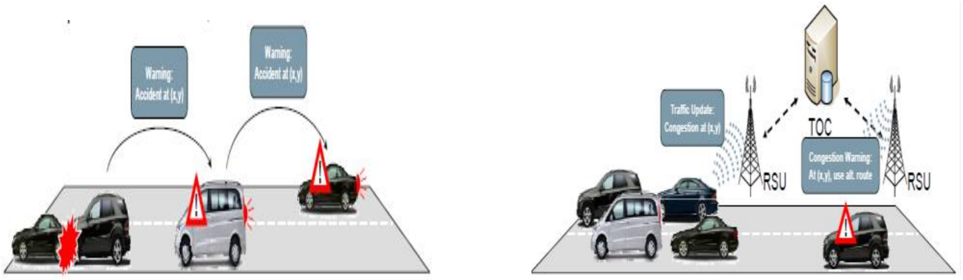

Figure 1 V2V and V2I communication scenarios

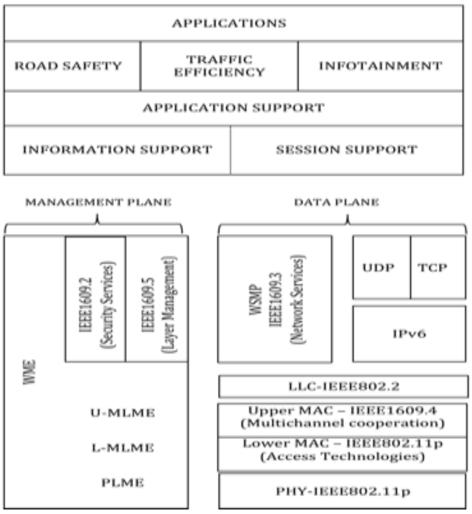

Figure 2 WAVE Protocol Stack

WAVE protocol stack shown in Figure 2 specifies the standards that covers the functionalities at each layer. A higher layer standard, IEEE1609 functions in the middle layers of protocol stack to support safety applications, while TCP, UDP & IP protocols are used to support non-safety applications. The IEEE 1609 standards set consists of four versions and their functions for VANET are discussed below.

- IEEE1609.0 - defines overall architecture of WAVE, communication model, mechanisms to wireless medium access, overall structure of components as OBU and RSU WAVE interfaces.
- IEEE1609.1 - describes resource manager in WAVE system which allows an OBU with limited computing capacity to run processes remotely.
- IEEE1609.2 - specifies security services in WAVE, defines message format and processing
- IEEE1609.3 - describes services of network layer for VANET, specifies routing and routing based on level 3 of OSI model and IP, UDP, TCP and WSMP protocols. WAVE short message protocol (WSMP) defined by 1609.3 is dedicated to safety applications, while IPV6 and TCP/UDP supports non-safety applications.
- IEEE1609.4 - describes multichannel operation that implements physical layer including the parameters for prioritizing messages, timers, channel switching and primitive design for multichannel operation. Figure 2 explains the V2V and V2I communication scenarios.

Cognitive Radio enables the detection of idle channels for vehicular communication and hence can assist the timely broadcast of safety messages[3]. CR estimates the availability of idle channels (also called spectrum holes or White spaces) by defining two types of users, licensed Primary User (PU) and unlicensed Secondary User (SU). The Secondary Users are allowed to detect the unused spectrum resources licensed to the Primary Users and are not in use currently. These identified vacant channels of the PU can be accessed by the SUs for temporary data transmission as long as no interference is caused to the PUs. The primary objective of the CR technology is to provide highly reliable communications and utilize the available radio spectrum efficiently. This is done by implementing four phases of the Cognition Cycle as shown in Figure 3.

- Sensing: The channel selection and vacant PU spectrum are identified.
- Analysis and decision: With the vacant channel information obtained, the best channel for transmission is selected based on various factors like interference, path loss, delay.
- Sharing: The distribution of the available spectrum among the SUs is managed while maintaining the Quality of Service (QoS).
- Mobility: When a PU arrives, the SU must move from one channel to another unused channel for continuous transmission. The switching of an SU from one channel to other is referred to as spectrum mobility.

The CR framework in VANET prioritizes the critical safety messages while ensuring that non-critical infotainment messages are delivered with less latency and improved overall network performance. Figure 3 depicts a V2V communication scenario with CR-enabled cars, allowing for opportunistic spectrum utilization while on the move.

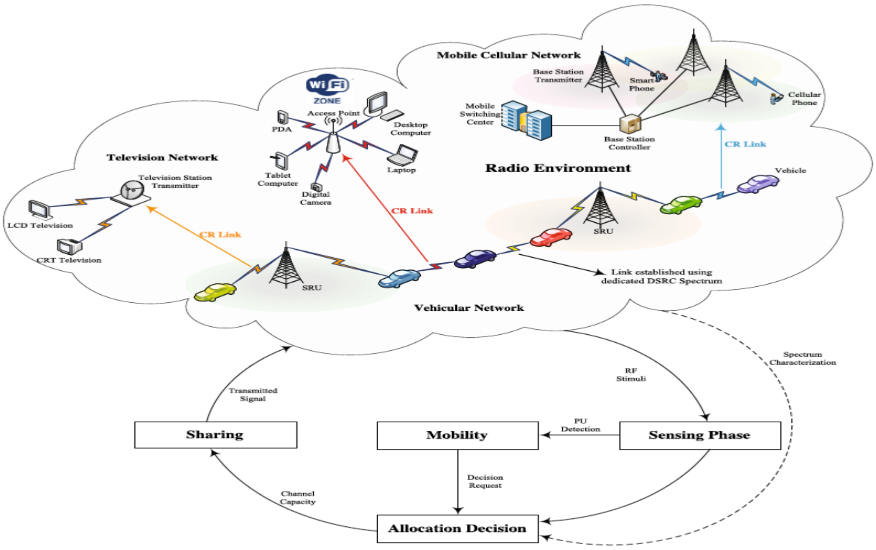

Figure 3 Vehicular Environment and Cognition Cycle

## II. SPECTRUM SENSING IN COGNITIVE VEHICULAR NETWORKS

The integration of CR technology with vehicular networks has been proved to be a potential solution for resolving the spectrum insufficiency in Vehicular Networks. Spectrum sensing is a vital task in CR technology which helps an SU identify the vacant PU channels to enable opportunistic spectrum access, thereby improving the spectrum utilization[7]. In particular, the estimation of the available spectrum holes and the predicted length of the spectrum holes is of utmost importance as the performance of the network gets severely affected if the SUs cannot identify vacant bands in a timely and accurate manner. Hence, reliable and accurate sensing of PU spectrum is of primary importance in the design of spectrum sensing technique. The spectrum sensing task performed by vehicular users in a Cognitive Vehicular environment is shown in Figure 4. The various spectrum sensing techniques proposed in the literature provide additional channel bandwidth by efficiently monitoring the ongoing transmissions, their current transmission data and precise locations using individual or cooperative sensing data aggregation. Several researchers have been conducting experiments to assess the quality of a spectrum sensing technique in improving the spectrum utilization for vehicular communications. The use of CR technology in vehicular networks is still a relatively new research topic, with many unanswered questions. Many authors identified open issues for effective radio spectrum sensing in Cognitive Vehicular Networks, such as high-speed mobility of vehicles, dynamic topology, lack of coordination among the SUs in a dynamically-changing availability of channels and so on.

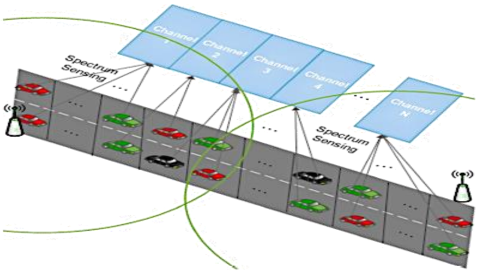

Figure 4 Spectrum sensing in Cognitive Vehicular Network

The performance of a spectrum sensing technique is assessed using sensing efficiency and sensing accuracy. While sensing efficiency is represented by sensing overhead and network throughput, sensing accuracy is denoted by the metrics Probability of detection ($P_d$) and Probability of false alarm ($P_f$). The Probability of detection measures how correctly an SU detects the presence of PU and Probability of false alarm finds the channel to be busy when free. For reliable sensing performance, $P_d$ must be as high as possible and $P_f$ must be low. To achieve this, more time must be spent on sensing which leaves less time for transmission. This results in low throughput of the SU due to sensing-throughput trade-off. The loss of SUs transmission opportunity when borrowed for cooperative sensing is termed as sensing overhead. However, the sensing efficiency can be improved by identifying more no. of channels with optimal selection of SUs participating in sensing process thereby increasing the throughput.

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## III. TYPES OF SPECTRUM SENSING TECHNIQUES

The spectrum sensing approaches can be broadly categorized into non-cooperative and cooperative techniques. The sensing ability of a single SU in non-cooperative approach is affected by dynamic topology, high mobility and unreliable wireless channel. Hence, Cooperative Spectrum Sensing(CSS) using multiple SUs is proposed to increase the sensing performance and support the transmission of high-priority safety messages[8]. The CSS approach allows all the SUs to perform sensing at the same time, and then report the local sensing reports to the fusion centre in a centralized architecture or among themselves in a distributed architecture to make the final global decision on the channel status. The CSS is more accurate than individual sensing, since the global decision can be made based on multiple sensing reports. It is also evident that the interference caused to the PU is reduced because of the cooperation among the secondary users but involves increased complexity and delay.
The various spectrum sensing approaches used by Cognitive Vehicular Networks for the PU detection include Energy Detection, Matched Filter detection, Cyclostationary Feature Detection and other techniques that improves the spectral detection.

### A. *Energy Detection technique*

Energy Detection is the popularly employed sensing scheme as it does not depend on any prior information about the PU transmission and is easy to implement. Operationally, the Energy Detection approach works in two steps. In the first step, the energy of the PU signal to be detected over a particular spectrum band is measured. In the second step, the existence of Primary User in the channel is decided by comparing the measured energy with a predefined threshold, λ.

The energy detection method senses the spectrum based on simple binary hypotheses given by

$$\mathscr{H}0 : y(n) = w(n)$$

$$\mathscr{H}1 : y(n) = x(n) + w(n)$$

where y(n) - Received signal at CR user
x(n) - PU transmitted signal
w(n) - Noise affecting the transmitted signal
$\mathscr{H}0$ - Detection of noise only (Null Hypotheses)
$\mathscr{H}1$ - Detection of noise and PU transmitted signal. (Hypotheses of PU presence)

The detection performance of energy detection approach is easily affected by noise uncertainty which increases the possibility of false detection, that affects the priority of PU.

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### B. *Matched Filter technique*

In the matched filter approach, the input signal is correlated with a stored replica of the signal. The output is compared with the predefined threshold for decision making. This approach performs poorly when SU has no information about the PU signal. Another limitation is the need for complex hardware. The major advantage is it requires less time to achieve high processing gain due to coherent detection.

### C. *Cyclostationary Feature Detection*

The Cyclostationary feature detection approach detects the presence of the PU signal by using the periodicity in the autocorrelation of the modulated signals. This technique too requires a prior knowledge on the PU signal and performs good when compared to energy detection particularly at low signal-to-noise ratios (SNR) regime as it is robust against random noise and interference.

Also, hybrid sensing approaches which combine two or more sensing techniques is a novel idea implemented in the recent articles. The primary challenge in spectrum sensing is identification of weak signals in a noisy environment with small probability of miss detection.

## IV. FUSION TECHNIQUES

To improve the sensing performance in CSS, an efficient fusion technique is needed to make the global decision on the channel availability. Researchers employed hard and soft fusion rules to increase the detection performance[11]. Based on the individual decisions from each SUs, three popular hard fusion rules exists.

- AND rule: Spectrum assumed to be available only when one SU declares there is no PU.
- OR rule: Spectrum assumed to be available only when all SUs declare there is no PU.

- Majority rule(k out of M): Based on majority of the individual decisions. If the result from more than half of the SUs is of one hypothesis, then that particular hypothesis is made as final decision.

Soft fusion techniques like Maximum Ratio Combining(MRC), Equal Gain Combining(EGC) and so on were discussed in the literature for improved accuracy but at the cost of bandwidth.

## V. CONCLUSION

This study provides an overview of VANET communication standards and the major challenges faced in its deployment. In particular, to alleviate the spectrum shortage issue, the scope of implementing CR technology in Vehicular Networks is discussed. The Cognitive Vehicular Network has significant potential in the near future in intelligent transportation systems (ITS), despite the fact that the design and implementation of CR technology in VANET is still in the initial stages. As VANETs has unique characteristics that must be considered when developing spectrum management functions for Cognitive Vehicular Networks, existing research solutions for general Cognitive Radio Networks cannot be directly applied. This paper identifies several spectrum sensing techniques and the requirements pertinent to sensing for the effective design and implementation of Cognitive Vehicular Networks.

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