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Spectrum Sensing For Cognitive Radio Employing Time-Domain Signal Cross Correlation For Vehicular Ad-Hoc Networks

Ms.Shruthi R[1], Mrs. Sharmila K.P[2]
[1,2.] *(Telecommunication, CMRIT, India)*

Abstract *- Recent advancement in vehicular wireless applications is also a major contributing factor in spectrum scarcity. Cognitive radio technique is applied to Vehicular Ad hoc Networks (VANETs) to increase frequency bandwidth. Fast and reliable detection of primary user is the key component of cognitive radio networks. In this paper, we are considering a CR system that uses spectrum sensing based on the Time-Domain Symbol Cross-correlation (TDSC) technique, This paper examines the performance of spectrum sensing using Time-Domain Symbol Cross-correlation over correlated Rayleigh channel, in the context of the Vehicular Ad-Hoc Networks for which the TDSC method is explained analytically and illustrated with numerical results obtained from simulations. The relevant simulation results are presented to support our analytical results for average miss detection probability.*

Keywords *- cognitive radio, spectrum sensing.*

I. Introduction

A Vehicular Ad-Hoc Network, or VANET, is a form of mobile ad-hoc networks(MANETs), to provide communications among nearby vehicles and between vehicles and nearest fixed equipment, usually described as roadside equipment.

The VANET used to providing safety and comfort for passenger. Having VANET inside vehicle need only small electronic device, which will provide Ad-Hoc Network connectivity for the passengers inside the vehicle. By this device operating this network does not need complicated connection and server communication. Each vehicle equipped with VANET device will be a node in the Ad-Hoc network and can receive and relay others messages through the wireless network.

The U.S Federal Communication Commission has allocated seven 10-MHz channels over the 5.9-GHz band for dedicated short-range communication (DSRC) to support the first class of applications for road safety, while the second class scavenges the remaining spectrum resources. Obviously, the second class of applications for wireless services could be subjected to starvation of spectrum resources, which impairs economic scales and prevalence of such applications Furthermore, in the extreme case that the licensed spectrum resource utilization is oversaturated due to traffic jams for emergency incidences in the network area, neither of the two applications can be well satisfied. To solve this problem of possible spectrum resource starvation in VANETs, a technique is proposed to exploit licensed but unused frequency bands. Cognitive radio (CR)[1] is one of the most exciting advances of telecommunications in the past few years. In addition to a great solution to the spectrum starvation problem, CR is suitable in VANETs due to its highly mobile and dynamic networking environment. Similar to many cognitive radio systems, CR-VANETs faces the challenge of spectrum sensing with high reliability. The vehicular environment vision requires reliable, low latency wireless communication methods. In CR-VANETs, Time-Domain Symbol Cross-correlation (TDSC)[2] can be applied to decrease bandwidth scarcity. The TDSC algorithm is based on the observation that the cross-correlation of two OFDM symbols in time domain has a non-zero component if the two symbols correspond to pilot tones, and the studied spectrum sensing technique is applicable to any OFDM scheme that shares frequency-domain pilot symbols for synchronization and frequency estimation [3], [4].The paper is organized as follows. In section II, detailed model of CR-VANETs and spectrum sensing algorithm with its significance in vehicular networks is discussed. The approximated expression for average miss detection probability over correlated Rayleigh fading is obtained in section III, followed by the simulation results of spectrum sensing method and conclusion.

II. System Model

A. Network Model:

To improve the VANETs economic scale and efficiency, vehicular communication devices are equipped with CR to utilize the very-high-frequency (VHF)/UHF TV broadcast frequency bands when the 5.9-GHz licensed spectrum band is not available. Licensed TV bands holders are primary users (PUs) whereas vehicles and roadside infrastructure on high ways and suburban cities will act as secondary users (SUs). channels between PU and SUs are assumed to be independent and identically distributed. For sake of simplicity, let us consider a scenario where vehicles follow the freeway mobility model, as shown in Fig.1.

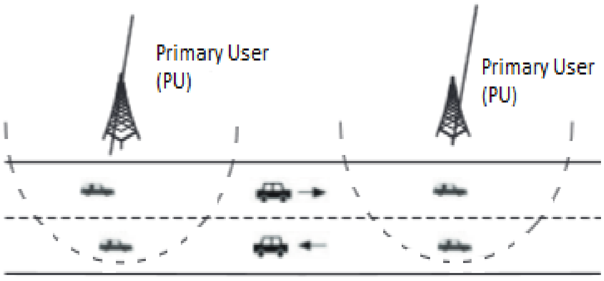

Fig. 1. A deployment scenario for CR-VANETs

B. Time-Domain Symbol Cross-correlation Based Technique For Spectrum sensing

Let the n-th sample of the l-th OFDM symbol be expressed as [6]

$$x_l[n] = e^{j(2\pi f \Delta n/N + \theta_l)} \cdot \frac{1}{N} \sum_{k=0}^{N-1} H[k] X_l[k] e^{j2\pi kn/N} + w_l[n] \quad (1)$$

where: f is the carrier frequency offset normalized to the subcarrier spacing, is the initial phase of the l-th OFDM symbol, M = N + L is the length of an OFDM symbol, and N is the number of subcarriers, $X_l[k]$ are the data symbols at the k-th subcarrier of the l-th OFDM symbol. The complex channel gain of the k-th subcarrier is denoted by H[k], $w_l[n]$ is a sample of a complex additive white Gaussian noise (AWGN) process assumed to be a circularly symmetric complex Gaussian random variable with variance of w2=N. The TDSC is defined as

$$R(l, m) = \frac{1}{N} \sum_{n=0}^{N-1} x_l[n] x_m^*[n] \quad (2)$$

where it is assumed that the l-th and m-th OFDM symbols have the same pilot tone positions. After calculations that are omitted due to space constraints but can be found in [5] we get that the TDSC is expressed as

$$R(l, m) \cong e(l-m) \cdot \frac{\rho^2}{N^2} \sum_{k \in \mathbf{P}_a} |H[k]|^2 + \frac{1}{N} \sum_{k=0}^{N-1} w_l[n] w_m^*[n]. \quad (3)$$

For this OFDM symbol at specified positions pilot signals are inserted. This pilot signal will represent start of header data and the end of trailing data. It is a known sequence of data used to identify frame start, also called reference signal or midamble in wireless communications. Here midamble means fixed periods (data positions) of time with some synchronization data pattern rather than random ones. Always we call that as training sequence. Given a channel. For every channel slot pilot positions will be defined. Only in those positions pilot data has been inserted. For every OFDM symbol, pilot symbols will be inserted in those positions.

Whenever a given channel is in use, in one buffer one of the OFDM symbol will be saved. To check whether the channel is in use, newly coming OFDM symbol will be cross correlated with buffered OFDM symbol.

III. Performance Analysis

In this section, we find the average detection probability over Rayleigh fading channel with no diversity. For sake of simplicity it's been used a single-path channel, the probability of misdetection PMD is expressed as

$$P_{MD} = 1 - Q_{x_2'^2(\lambda)} \left(\frac{\gamma^2}{\sigma_{H_1}^2} \right). \quad \textbf{(4)}$$

Where the function Q corresponds to the right-tail of the non-central Chi-Squared distribution with two degrees of freedom.

IV. Numerical And Simulation Results

In this section we present simulation results corresponding to application of the TDSC technique for sensing of VANETs OFDM signals. The performance of TDSC technique for vehicular communications is presented in terms of average miss detection probability. At the fixed speed, vehicle mobility yields a better performance in urban environments due to the short decorrelation distance.

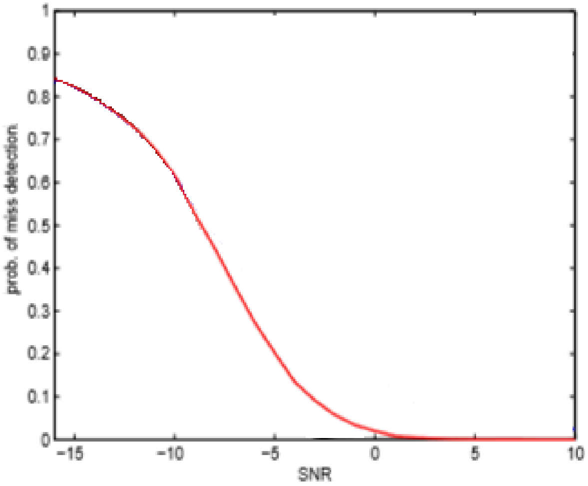

Fig. 2 The average probability of mis-detection for various SNR

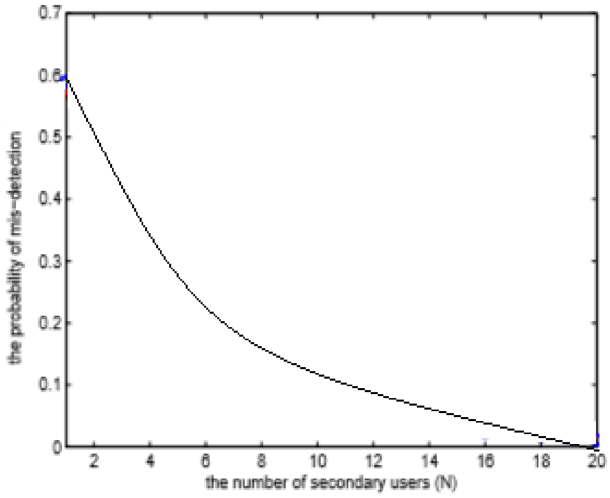

Fig. 3 The average probability of mis-detection for various number of SUs

Fig.2 shows the average probability of miss detection vs SNR for the correlated Rayleigh channel. Fig.3 shows the average probability of miss detection for various secondary users. As expected, P_{MD} decreases as the number of users increases regardless of the vehicle speed.

V. Conclusion

In this paper we study the performance of spectrum sensing algorithm based on Time-Domain Symbol Cross-Correlation (TDSC) method applied to Vehicular Ad-Hoc Networks. The method proposed provides a good performance at low SNRs.

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