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A reliable Spectral Detection Method of Dynamic Channel assignment in Wireless and Mobile Communication Networks

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ABSTRACT

The article analyzes the problem of energy efficient techniques in cooperative spectrum sensing (CSS). Although it was proven that single-device sensing is not sufficient for reliable sensing, cooperative spectrum sensing was proposed, burdened, however, with great overhead. This paper investigates the issue of robust and efficient cooperative spectrum sensing in CVNs. We propose robust cooperative spectrum sensing via low-rank matrix recovery (LRMR-RCSS) in cognitive vehicular networks to address the uncertainty of the quality of potentially corrupted sensing data by utilizing the real spectrum occupancy matrix and corrupted data matrix, which have a simultaneously low-rank and joint-sparse structure. Considering that the sensing data from crowd cognitive vehicles would be vast, we extend our robust cooperative spectrum sensing algorithm to dense cognitive vehicular networks via weighted low-rank matrix recovery (WLRMR-RCSS) to reduce the complexity of cooperative spectrum sensing.

1. INTRODUCTION

Spectrum sensing is the key function of CR technology to identify available spectrums. To this end, several spectrum sensing methods have been proposed and investigated in [3] and references therein. However, spectrum sensing techniques do not always guarantee satisfactory performance due to noise uncertainty and channel fading, which are the fundamental characteristics of dynamically changed wireless channel. Once the PU signal experiences deep fading or blocked by obstacles, the power of the PU signal received at the SU may be too weak to be detected [4]. A well-known approach for detecting the PU activity is cooperative spectrum sensing (CSS) where a set of SUs cooperate by fusing their sensing information with each other and collectively deciding on the presence or absence of the PU to enhance the reliability of sensing results.

But the nature of aggregating data makes CSS open a window for attackers to sneak into collaborative SUs, who will send out falsified local spectrum inference to the fusion center (FC). During such an assault, attackers can prevent reliable SUs from using the existing white space, or allure them to access the channels in use and cause excessive interference to PUs [5]. This typical sort of attack in CSS is Byzantine attack, which is also referred to as spectrum sensing data falsification (SSDF), in pursuit of the CSS performance degradation, thereby undermining the premise of CR technology.

However, both theoretical analysis and simulation results indicate that the currently allocated bandwidth is not sufficient to provide reliable safety-related services under certain heavy traffic conditions [4–7].The generation rate of a typical basic safety message (BSM) is from 2 to 10 messages per second to support many safety-related applications [6]. The high probability of an increased BSM generation rate in a heavy traffic environment will lead to the CCH becoming congested due to an increased number of packet collisions. This congestion will decrease the reliability of vehicular communication. Moreover, certain studies have demonstrated that non-safety-related services of the allocated band might also have to be severely restricted in high-density traffic. Reference [7] proved that a large share of nonsafety-related services only appropriates in low or moderate traffic conditions. Additionally, only 10% of the bandwidth would remain for non-safety-related applications in order to guarantee 95% of the reliability of transmissions for safety related applications in a high traffic environment.

Cognitive radio (CR) technology is a feasible measure that has been used to solve the spectrum scarcity problems in vehicular networks (see, e.g., the recent overviews in [8, 9]). In cognitive vehicular networks (CVNs), as unlicensed users, the vehicles equipped with CR can detect and use other idle licensed spectrums when the primary user (PU) is absent. Cooperative spectrum sensing (CSS) has been extensively investigated in efforts to improve the detection performance via the diversity gain of cooperative secondary users (SUs) in CVNs. These papers have shown that CSS can achieve spatial diversity gains under the assumption that the collaborative SUs are proactive. However, none of these studies have considered that SU sensing data may be unreliable due to either certain malicious behaviors or unexpected equipment failures. Many envisioned applications in vehicular networks that are related to safety would need high reliable connectivity.

Therefore, some preliminary work has focused on increasing the robustness of cooperative spectrum sensing in cognitive vehicular networks. However, it is hard to implement these methods in practical CVNs environment due to their complexity, especially under heavy traffic conditions. While moving on the road, it is difficult to detect a malicious vehicle that may be transmitting untrustworthy spectrum sensing data during a sensing period. One challenge in CSS is the uncertainty of the sensing data quality, which may be corrupted by unreliable vehicles.

Besides the effective spectrum utilization, the overall energy efficiency of a wireless network has been recognized as the key paradigm of the future 5th generation (5G) radio communication systems. This is because the mentioned exponential increase of mobile data traffic significantly contributes to the world-wide consumed energy and related CO2 footprint. For the future communication, Energy Efficiency (EE) of wireless systems is required to be improved by the factor of 10. In these systems, in which cognition capabilities are in place, the protection of PU transmission from the interference generated by secondary users (SUs) of the CR system is a prerequisite. As PUs can start and complete transmission at any moment, sensing should be the permanent process, and it may consume a Considerable amount of energy. Thus, energy-efficient sensing is an important issue, and it has been addressed by a number of studies.

This survey article merges the mentioned spectrum and energy efficiency: on the one hand, it considers the idea of spectrum sensing, on the other the aspect of energy efficiency is underlined and relevantly discussed. The main goal of this paper is to analyze, and classify various spectrum sensing methods according to the possible ways of energy savings; the presented classification is also the main novelty of this contribution. Following the survey analyses, e.g., as presented, where specific aspects of spectrum sensing are provided, and, where the optimum spectrum sensing is discussed, in this work, we intentionally focus on energy efficiency in cooperatively-sensing networks.

1.1 PROBLEM STATEMENT

While moving on the road, it is difficult to detect a malicious vehicle that may be transmitting untrustworthy spectrum sensing data during a sensing period. One challenge in CSS is the uncertainty of the sensing data quality, which may be corrupted by unreliable vehicles. This uncertainty motivated us to investigate the issue of efficient and robust CSS in CVNs. We formulate an optimization problem as a low-rank and sparse recovery by utilizing the real spectrum occupancy matrix and corrupted data matrix, which have a simultaneously low-rank and joint-sparse structure. In our previous work, our model simply assumed that cognitive vehicles carried out low-speed and single movement on a highway. But this assumption, apparently, is not always conformed to the real case, considering that, in CVNs, vehicle density reveals sparse and dense fluctuations with the space and time. As there are few users participating in cooperative sensing with sparse traffic flows, it is impossible to improve the detection probability of cooperative spectrum sensing

2. LITERATURE REVIEW

Jun Wu, have proposed Cooperative spectrum sensing (CSS) is envisaged as a powerful approach to improve the utilization of scarce radio spectrum resources, but it is threatened by Byzantine attack. Byzantine attack has been becoming a popular research topic in both academia and industry due to the demanding requirements of security. Extensive research mainly aims at mitigating the negative effect of Byzantine attack on CSS, but with some strong assumptions, such as attackers are in minority or trusted node(s) exist for data fusion, while paying little attention to a mobile scenario. This paper focuses on the issue of designing a general and reliable reference for CSS in a mobile network. Instead of the previously simplified attack, we develop a generic Byzantine attack model from sophisticated behaviors to conduct various attack strategies and derive the condition of which Byzantine attack makes the fusion center (FC) blind. Specifically, we propose a robust sequential CSS (SCSS) against dynamic Byzantine attack.

Xia Liu, have proposed in cognitive vehicular networks (CVNs), many envisioned applications related to safety require highly reliable connectivity. This paper investigates the issue of robust and efficient cooperative spectrum sensing in CVNs. We propose robust cooperative spectrum sensing via low-rank matrix recovery (LRMR-RCSS) in cognitive vehicular networks to address the uncertainty of the quality of potentially corrupted sensing data by utilizing the real spectrum occupancy matrix and corrupted data matrix, which have a simultaneously low-rank and joint-sparse structure. Considering that the sensing data from crowd cognitive vehicles would be vast, we extend our robust cooperative spectrum sensing algorithm to dense cognitive vehicular networks via weighted low-rank matrix recovery (WLRMR-RCSS) to reduce the complexity of cooperative spectrum sensing.

Amardeep A have proposed, Cooperative relay based spectrum sensing techniques are primarily available techniques in the field of research in cognitive radio networks. Even such techniques are available there is need to consider fundamental effects on spectrum sensing with various combination of scenarios that lead to false alarm detection. In this paper we have compared the three cases of cooperative spectrum sensing to analyze the effects and to form the direction of further research expectations in the field of cooperative spectrum sensing.

Krzysztof Cicho´, have proposed the article analyzes the problem of energy efficient techniques in cooperative spectrum sensing (CSS). Although it was proven that single-device sensing is not sufficient for reliable sensing, cooperative spectrum sensing was proposed, burdened, however, with great overhead. Thus, work on the topic of energy efficient cooperative schemes gained more interest, which resulted in a number of energy efficient cooperative algorithm proposals. In this work, we try to classify the possible directions in energy efficient CSS and present a limited set of works introducing new ideas to an energy efficient CSS algorithm.

F. Richard Yu, have proposed cognitive radio mobile ad hoc networks (CR-MANETs), secondary users can cooperatively sense the spectrum to detect the presence of primary users. In this chapter, we propose a fully distributed and scalable cooperative spectrum sensing scheme based on recent advances in consensus algorithms. In the proposed scheme, the secondary users can maintain coordination based on only local information exchange without a centralized common receiver. We use the consensus of secondary users to make the final decision. The proposed scheme is essentially based on recent advances in consensus algorithms that have taken inspiration from complex natural phenomena including flocking of birds, schooling of fish, swarming of ants and honeybees. Unlike the existing cooperative spectrum sensing schemes, there is no need for a centralized receiver in the proposed schemes, which make them suitable in distributed CR-MANETs.

3. COOPERATIVE SPECTRUM SENSING

The main goal of spectrum sensing is to identify the presence or absence of a PU at a certain location, at a given moment, and in a specified frequency band (Fig. 1). Spectrum sensing in its simplest non-cooperative form is considered as single device (or single-node) sensing, where each node makes an independent decision on the availability of a frequency band, and acts accordingly (transmits in this band or not). From this perspective, numerous spectrum sensing algorithms have been proposed, such as the ones described.

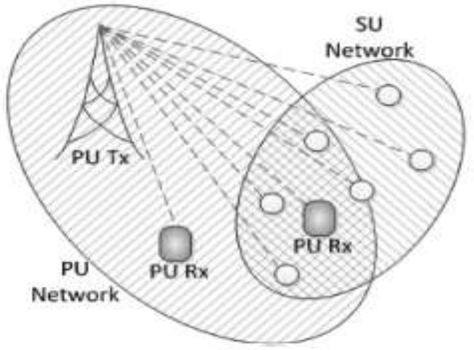


Fig. 1. Illustration of the primary and secondary user coexistence in the cognitive radio network.

Fig. 2. Cooperative spectrum sensing procedure.

However, several investigations pointed out that sensing carried out locally by single devices is not accurate enough for the safe coexistence of primary and secondary users. Thus, it is generally agreed that one of the ways to increase the reliability of spectrum sensing is to apply cooperation between nodes. In cooperative spectrum sensing every node in a cognitive network senses the spectrum, and reports local sensing results, which are then used for acquiring a global decision characterized by the global probability of detection (see Fig. 2). In the following subsections each of these phases will be discussed in detail.

3.2 Individual and Cooperative Spectrum Sensing

Spectrum sensing can be conducted either non-cooperatively (individually), in which each secondary user conducts radio detection and makes decision by itself, or cooperatively, in which a group of secondary users perform spectrum sensing by collaboration. No matter in which way, the common topology of such a cognitive radio network can be depicted as in Fig. 2. Individual spectrum sensing is conducted by secondary users on its own, and each user has a local observation and a local decision accordingly. Thus, in Fig. 2, each secondary user performs the spectrum sensing locally and no communication is between one another, nor is the common receiver (fusion center). In such a condition, cognitive radio sensitivity can only be improved [6] by enhancing radio RF front-end sensitivity, exploiting digital signal processing gain for specific primary user signal, and network cooperation where users share their spectrum sensing measurements. However, if the sensing channels are facing deep fading or shadowing, then affected individuals will not be able to detect the presence of the primary user, which leads to missing detection failure.

In order to improve the performance of spectrum sensing, several authors have recently proposed cooperation among secondary users. Cooperative spectrum sensing has been proposed to exploit multi-user diversity in sensing process. It is usually performed in three successive stages: sensing, reporting and broadcasting. In the sensing stage, every cognitive user performs spectrum sensing individually. This can be shown as in Fig. 2, where secondary users try to collect the signal of interest through sensing channels. In the reporting stage, all the local sensing observations are reported to a common receiver via reporting channels (see Fig. 2) and the latter will make a final decision on the absence or the presence of the primary user. Finally, the final decision is broadcasted via broadcast channels to all the secondary users concerned, which include not only the ones involved into the sensing stage, but also those that do not have sensing capabilities but want to participate into the spectrum sharing stage.

3.2 Centralized Cooperative Spectrum Sensing

Although some research activities have been conducted in cooperative spectrum sensing, most of them use a common receiver (fusion center) to do data fusion for the final decision whether or not the primary user is present. However, a common receiver may not be available in some CR-MANETs. Moreover, as indicated, gathering the entire received data at one place may be very difficult under practical communication constraints. In addition, authors of [4] study the reporting channels between the cognitive users and the common receiver. The results show that there are limitations for the performance of cooperation when the reporting channels to the common receiver are under deep fading. In summary, the use of a centralized fusion center in CR-MANETs may have the following problems (see Fig. 2):

- Every secondary user needs to join/establish the connection with the common receiver, which requires a network protocol to implement.
- Some secondary users need a kind of relay routes to reach the common receiver if they are far away from the latter.
- Communication errors or packet drops can affect the performance of such a network if more users have worse reporting channels (e.g. Rayleigh Fading) to reach the common receiver.
- There should be a reliable wireless broadcast channel for the common receiver to inform each of every user once there is a decision made.
- The current centralized network does not fit for the average calculation of all the estimated sensing energy levels, because it requires the common receiver to correctly receive all the local estimated sensing results. Otherwise, the decision precision cannot be guaranteed.

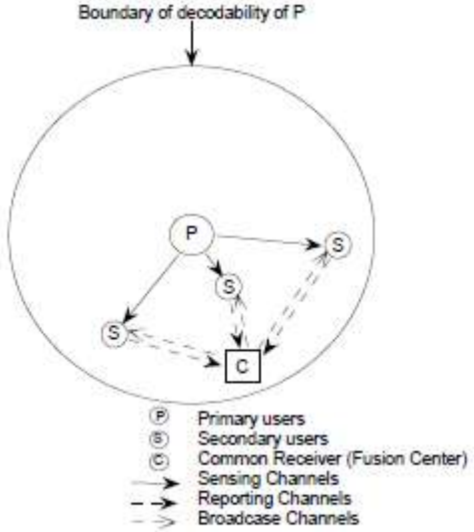


Fig. 2: A typical cognitive radio network.

4. PROPOSED ALGORITHMS

4.1. Robust Cooperative Spectrum Sensing via Low-Rank Matrix Recovery in CVNs (LRMR-RCSS). Here, we introduce a matrix $\mathbf{X}M\times N$ fl $\mathbf{R}M\times N\mathbf{O}N\times N$ that represents the energy detector output matrix. Matrix **X** is also low-rank because rank(**X**) ≤ min(rank(**R**), rank(**O**)). In such a CSS network, we must reconstruct the real energy matrix from the sensing data matrix at the FC by a low-rank matrix recovery technique [38–41]. The goal of recovering the spectrum occupancy statematrix**O**translates into approximately recovering matrix **X** because it is difficult to recover **O** directly. According to the current low-rank matrix recovery theory, to recover the low-rank matrix **X** from the sensing data matrix **Y**, it can be formulated as

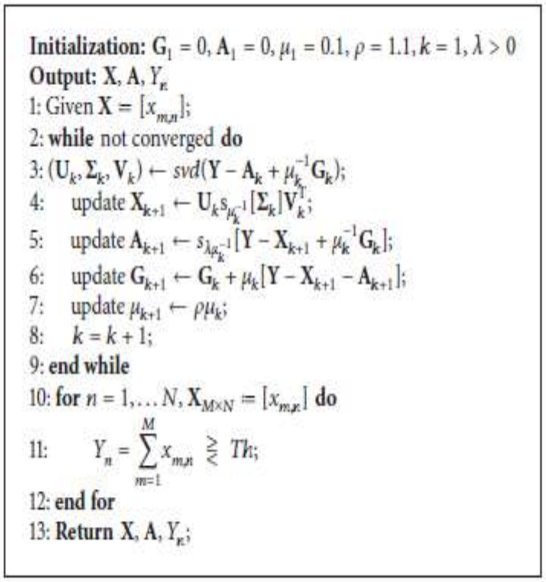
$$\min_{\mathbf{X},\mathbf{A}} \quad \operatorname{rank}(\mathbf{X}) + \lambda \|\mathbf{A}\|_0$$

$$\text{s.t.} \quad \mathbf{Y} = \mathbf{X} + \mathbf{A} + \mathbf{V}$$

Where rank(·) is the rank of the matrix, and ‖·‖0 is the number of nonzero entries in the matrix. λ is a positive rank-sparsity controlling parameter which represents a tradeoff parameter to balance matrix **X** and matrix **A**. According to previous research, we introduce a matrix **G** of the Lagrangian multiplier; then, model (above equation) could be transferred to minimizing the following augmented Lagrangian function$\mathcal{L}$:

$$\mathscr{L}(\mathbf{X}, \mathbf{A}, \mathbf{G}, \mu) = \|\mathbf{X}\|_* + \lambda \|\mathbf{A}\|_1 + \langle \mathbf{G}, \mathbf{Y} - \mathbf{X} - \mathbf{A} \rangle + \frac{\mu}{2} \|\mathbf{Y} - \mathbf{X} - \mathbf{A}\|_F^2$$

Computational Complexity Analysis. The primary computational cost of the LRMR-RCSS algorithm is the singular value decomposition (SVD) of an $M \times N$ matrix in the process of updating **X** when using the augmented Lagrangian multiplier (ALM) approach. Its computational complexity is (MNmin(M, N)).



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Initialization: $G_1 = 0, A_1 = 0, \mu_1 = 0.1, \rho = 1.1, k = 1, \lambda > 0$
Output: X, A, $Y_n$
Given $X = [x_{m,n}]$;
while not converged do
    $(U_k, \Sigma_k, V_k) \leftarrow svd(Y - A_k + \mu_k^{-1} G_k)$;
    update $X_{k+1} \leftarrow U_k s_{\mu_k^{-1}}[\Sigma_k] V_k^T$;
    update $A_{k+1} \leftarrow s_{\lambda\mu_k^{-1}}[Y - X_{k+1} + \mu_k^{-1} G_k]$;
    update $G_{k+1} \leftarrow G_k + \mu_k [Y - X_{k+1} - A_{k+1}]$;
    update $\mu_{k+1} \leftarrow \rho\mu_k$;
    $k = k + 1$;
end while
for $n = 1, \dots N, X_{M \times N} = [x_{m,n}]$ do
    $Y_n = \sum_{m=1}^{M} x_{m,n} \gtrless Th$;
end for
Return X, A, $Y_n$;
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Algorithm 1: Robust cooperative spectrum sensing via low rank matrix recovery in CVNs (LRMR-RCSS).

5. EXPECTED RESULTS

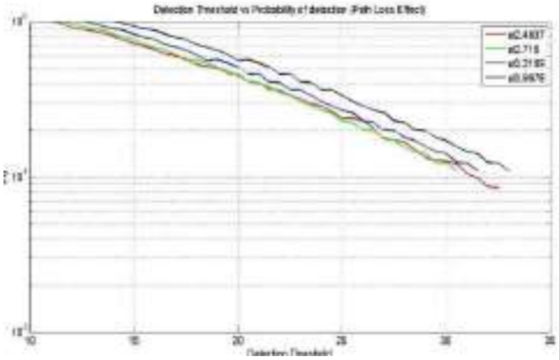

Figure 3: Probability of detection vs Detection Threshold

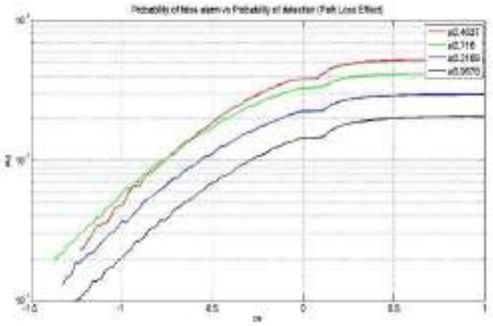

Figure 4: Probability of detection vs Probability of False alarm

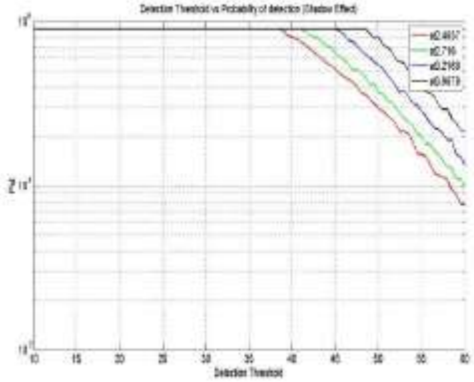

Figure 5: Probability of detection vs Detection Threshold

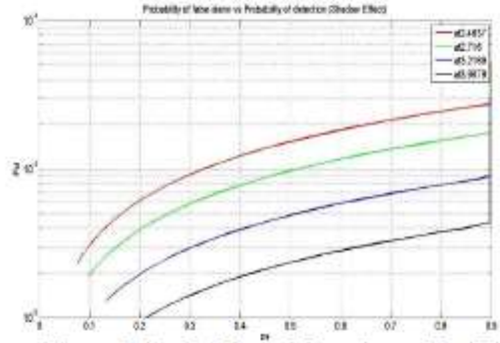

Figure 6: Probability of detection vs Probability of False alarm

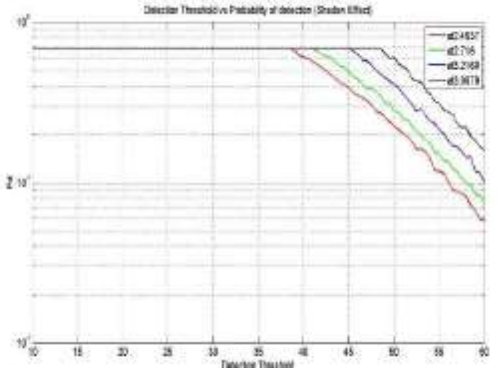

Figure 7: Probability of detection vs Detection Threshold

CONCLUSION

Cooperative sensing is an efficient method introducing additional detection gain at the cost of introduced communication overhead. In this survey we have briefly described the ways for obtaining energy-efficiency in cooperative sensing. This work investigates the issue of robust and effective cooperative spectrum sensing in cognitive vehicular networks. We establish a robust spectrum sensing algorithm, LRMR-RCSS, to eliminate the negative impact of corrupted sensing data. In addition, we extend our robust cooperative spectrum sensing algorithm WLRMR-RCSS while utilizing cooperative diversity into dense CVNs. The relevant methods can be applied in local (single-node) spectrum sensing procedures, in selection of cooperating, sensing, reporting and relaying nodes, in the application of the appropriate fusion rule, and finally in the proper network organization. We briefly presented algorithms leading to relative energy saving while assuring high sensing performance in terms of the global probability of detection or the global probability of false alarm.

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