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Cognitive Radio Security Issues: A Survey

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ABSTRACT

Energy-efficient and secure wireless communications have recently earned tremendous interests due to economic, environmental, military and many other concerns. Cognitive radio technology has been identified as an extraordinary tool to improve the energy efficiency of wireless networks. Cognitive techniques mainly include spectrum sharing, spectrum sensing and dynamic spectrum access, which are beneficial for the network performance of spectral efficiency, network security and energy efficiency. In this paper we investigate a survey for the physical layer security and energy efficiency in the cognitive radio and wireless sensor networks.

Keywords: Energy Efficiency, Secrecy Throughput, Cooperative Spectrum Sharing, Cognitive Radio Networks, Wireless Sensor Networks, Dynamic Spectrum Access.

INTRODUCTION

Cognitive radio technology has been identified as an extraordinary tool to improve the energy efficiency of wireless networks. Cognitive techniques mainly include spectrum sharing, spectrum sensing and dynamic spectrum access, which are beneficial for the network performance of spectral efficiency, network security and energy efficiency. On the other hand, cooperative techniques, such as cooperative relaying, cooperative jamming , and jointly cooperative relaying and jamming, have been proven to achieve improvements in wireless network performance, especially in terms of the energy efficiency and the secrecy performance . To be more specific, three cooperative relaying schemes were developed to increase the energy efficiency. In legitimate users created intentional jamming noise against eavesdroppers to acquire better secrecy rates. Han et al. Focused on the secrecy capacity optimization problem where security improvement is achieved through cooperative relaying and cooperative jamming [1].

Cognitive capability refers to the ability of the radio technology to capture or sense the information from its radio environment. This capability cannot simply be realized by monitoring the power in some frequency band of interest but more sophisticated techniques are required in order to capture the temporal and spatial variations in the radio environment and avoid interference to other users. Through this capability, the portions of the spectrum that are unused at a specific time or location can be identified. The cognitive capability provides spectrum awareness whereas re-configurability enables the radio to be dynamically programmed according to the radio environment. More specifically, the cognitive radio can be programmed to transmit and receive on a variety of frequencies and to use different transmission access technologies supported by its hardware design [2].

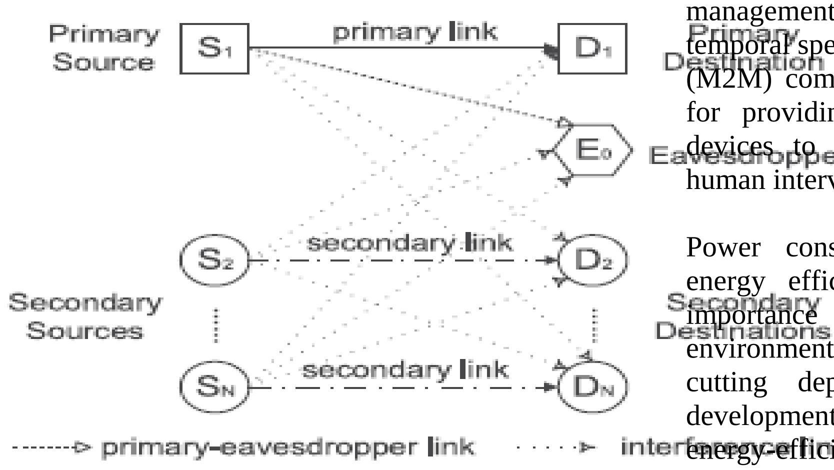

Figure 1: Work model with underlay CRNs. [1]

A key function of CR consists in the capability of acquiring the knowledge of the instantaneous spectrum status. Such capability can be accomplished by using geo-location techniques, by receiving control and management information or by performing spectrum sensing. Geo-location methods require a central database, self-locating capability and frequently updates of the database by license-holders. Likewise, control and management information techniques require both infrastructure elements and a database. On the other hand, spectrum sensing is considered the most promising solution for spectrum awareness [3]. Spectrum sensing is a periodic monitoring process of the spectrum, which is aimed at detecting the presence of the licensed users. Due to the high desired detection requirements, spectrum sensing performed by individual radios suffers from unreliable estimates in presence of multipath fading and shadowing. Thus, spectrum sensing is usually performed in a cooperative fashion among several altruistic cognitive users (CU), which are willing to share their individual sensing results in order to provide a more reliable global estimate of the spectrum occupancy.

After identification of available spectrum holes, the spectrum utilization can be improved through joint spatial and temporal spectrum sharing. SG applications, especially demand response management, can benefit from joint spatial and temporal spectrum sharing. Machine-to-machine (M2M) communication is an emerging paradigm for providing ubiquitous connectivity between devices to communicate autonomously without human intervention [7].

Power consumption optimization, and hence-energy efficient communication, is of crucial importance for CRNs as it reduces the environmental impact while simultaneously cutting deployment costs necessary to the development of green wireless networks. The energy-efficient criterion has gained considerable attention lately. Energy-efficient spectrum allocation in ad hoc CRNs is investigated in where the channel access problem is formulated as a joint power-rate control and channel optimization problem, with the objective to maximize the total capacity and minimize the power consumption of the system [5]. In below figure we show the energy efficient approach and their classification for the cognitive radio sensor networks [3].

Figure 2: The classification of the several energy-efficient CSS approaches found in the literature [3].

No cooperative spectrum sharing typically results in a reduced spectrum efficiency regime, but does not require frequent message exchanges. By contrast, in the cooperative spectrum sharing, a common technique is to form a cluster to share the users' information locally. The cooperative approaches tend to outperform the non-cooperative approaches and result in a certain fairness, as well as an improved throughput. On the other hand, the non-cooperative approach imposes a lower information exchange requirement and hence requires less energy [9].

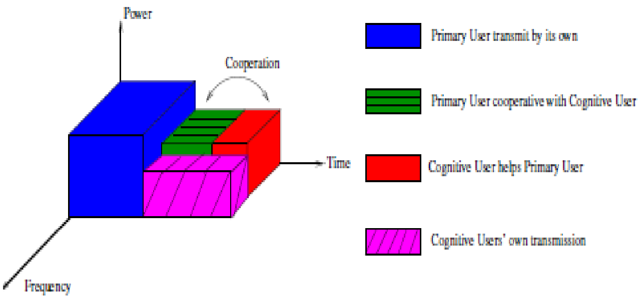

Figure 3: Overlay spectrum model of CR network.

The rest of this paper is organized as follows in the first section we describe an introduction of about the cognitive radio in wireless sensor network. In section II we discuss about the cognitive radio overview, In section III we discuss about the related work, their comparative study. Finally in section IV we conclude and discuss the future scope.

II COGNITIVE RADIO

Current wireless networks are characterized by static spectrum allocation policy, where spectrum is assigned to license holders on a long term basis. Due to continuous increase in spectrum demand, certain bands face severe scarcity and yet, a large portion of spectrum is often under-utilized across time and space. Apparent scarcity in spectrum arises from rigid frequency allocations rather than actual physical shortage of spectrum. Techniques facilitating flexible spectrum usage have been developed in order to solve these inefficiency problems. The key enabler of dynamic spectrum access is cognitive radio (CR) technology, which provides the capability for uni-licensed secondary users (SUs) to opportunistically access unused licensed bands (spectrum overlay approach) without causing harmful interference to primary users (PUs) [13]. Cognitive radio technologies can be divided into two main modes, namely; spectrum sensing and spectrum sharing. In the latter, the SU is required to detect the spectrum opportunities and then transmit while the PU is absent. In the former, SUs employ spectrum sharing technique while avoiding considerable interference to the primary receivers. In such systems, a medium access control layer protocol with ability to fairly allocate the spectrum between secondary users is required [15].

III RELATED WORK

[1] In this paper, author investigated the tradeoffs between the secrecy throughput and the energy efficiency in cognitive radio networks (CRNs), where primary and secondary users with different priorities of spectrum access can either interfere or cooperate with each other. To gain an understanding of the intricate effects that system parameters have on underlay network's performance, we exclusively focus on characterizing several key aspects that may have potential impacts on secure underlay CRNs, including the transmission power, the number of interfering users, and the designed interference resistance coefficient. Based on the obtained analytical results, they further proposed a cooperative spectrum sharing paradigm to improve both the secrecy throughput and the energy efficiency of primary users. The main idea is that primary users allow secondary users to simultaneously access the licensed spectrum and in return, the secondary transmitter acts as both a relay for primary transmissions and a friendly jammer against eavesdropping, in case the primary transmission fails. Both theoretical and numerical results reveal that when the interference from secondary transmitters is small, there is an optimal transmission power that maximizes the secrecy throughput for primary users compared to CRNs without the security issue and when the

interference from secondary transmitters is large, the secrecy throughput increases with the transmission power for primary users. [2] In this paper, they studied the outage performance of cognitive opportunistic decode-and-forward relaying operating in the secondary network with multiple PU receivers and in the presence of interference from a PU transmitter. A closed-form expression is derived for the outage probability with all system links following Rayleigh distribution. Furthermore, to get more insights about the system behaviour, the performance is studied at the high signal-to noise ratio (SNR) regime where approximate expressions for the outage probability, diversity order, and coding gain are obtained. Monte Carlo simulations are given to validate the achieved results. Main findings illustrate that with fixed interference power, the diversity order of the secondary system equals the number of relays and it is not affected by the number of PU receivers.

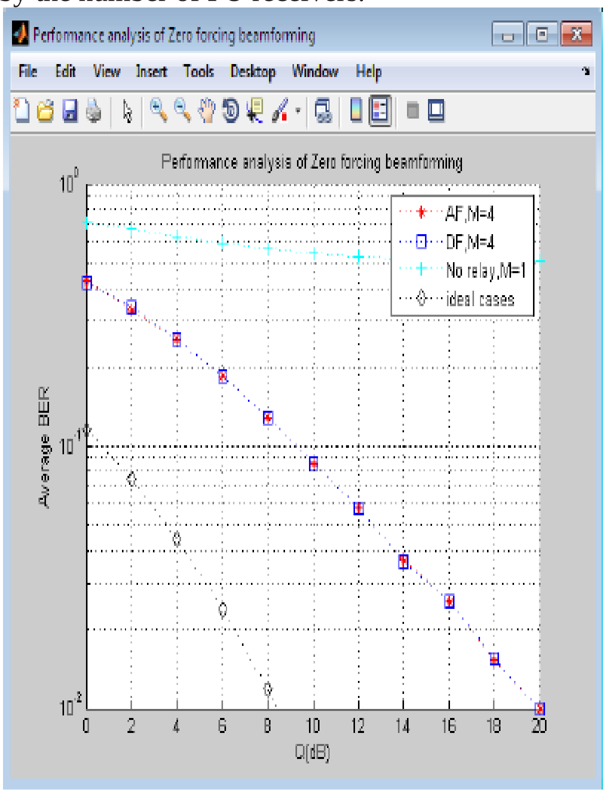

Figure 4: Performance analyzes of beam forming [2].

[3] In this paper, they provided an overview of state-of-the-art research that addresses the problem that is in cognitive radio networks (CRNs) is the high energy consumption, which may limit their implementation especially in battery-powered terminals. The large consumption mainly occurs during the spectrum sensing stage, especially if a cooperative approach is employed, and has an impact on the data transmission stage. Furthermore, they suggest important design guidelines of an energy-efficient framework for cooperative spectrum sensing. [4] In this paper, they defined the problems of physical layer security and energy efficiency through power control and relays' cooperation, where both decode-and-forward and amplify-and-forward protocols are considered. They proposed an one-leader one-follower Stackelberg (OLOFS) game model in the presence of multiple eavesdroppers, where optimal power allocation and pricing strategy can be determined to maximize the players' utilities. They also presented a best relay selection criterion for OLOFS game model in both perfect channel state information (CSI) and imperfect CSI scenarios, which maximizes the secrecy capacity of the network. A distributed learn- ing algorithm, inspired by the stochastic learning automata, is then proposed to achieve the equilibrium of the proposed games. They also derived closed-form intercept probability expressions of the direct transmission scheme and the proposed game model over Rayleigh fading channels in both decode-and-forward and amplify-and-forward protocols. [5] In this paper, they investigated energy-efficient cooperation for secrecy in cognitive radio networks. In particular, they considered a four-node cognitive scenario where the secondary receiver is treated as a potential eavesdropper with respect to the primary transmission. The cognitive transmitter should ensure that the primary message is not leaked to the secondary user by using Cooperative jamming. They investigated the optimal power allocation and power splitting at the secondary transmitter for our cognitive model to maximize the secondary energy efficiency (EE) under secrecy constraints. They formulated and analyze an important EE

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Stackelberg game between the two transmitters aiming at maximizing their utilities. They illustrated the analytical results through our geometrical model highlighting the EE performance of the system and the impact of the Stackelberg game. [6] In this paper, they considered the SEEE tradeoffs for cognitive radio (CR) networks with cooperative spectrum sensing (CSS). First, they formulated the general problem, and analyze two special cases: the SE maximization problem and the EE maximization problem. The SE and EE are optimized separately via joint optimization of sensing duration and final decision threshold in CSS. Based on the solutions of the two special cases, the general problem for SE-EE tradeoffs is solved. Then, they considered the tradeoffs of SE and EE from two perspectives: (a) maximizing EE while satisfying SE requirement; (b) maximizing SE while satisfying EE requirement. Efficient algorithms for sensing strategy design are proposed for each scenario. [8] In this paper, by utilizing the cognitive radio (CR) technique, they proposed a new type of CR enabled secondary WPCN, called cognitive WPCN, under spectrum sharing with the primary wireless communication system. Under this new setup, they proposed two coexisting models for spectrum sharing of the two systems, namely underlay and overlay based cognitive WPCNs, depending on different types of knowledge on the primary user transmission available for the cognitive WPCN. For each model, they maximized the sum-throughput of the cognitive WPCN by optimizing its transmission under different constraints applied to protect the primary user transmission. [10] In this paper, they proposed the energy efficiency of secure communication in an underlay cognitive radio network (CRN).They first formulated an optimization problem to maximize the secrecy energy efficiency (SEE) while meeting the quality-of service (QoS) requirement for the primary user and the transmit power constraint at each base station. Since the problem is non-convex and very difficult to solve, they converted the original fractional form into a subtractive one, and adopt the difference of two-convex functions (D.C.) approximation method to obtain an equivalent convex problem. [11] In this paper, they proposed a trade-off between the secrecy rate (SR) and energy efficiency (EE) in an underlay cognitive radio network (CRN) that consists of a cognitive base station (CBS), a cognitive user (CU), a primary user (PU), and multiple eavesdroppers (EDs). By using a so-called secrecy energy efficiency (SEE), which is defined as the ratio of SR to the total power consumption of CBS, as the design criterion, they formulated a secrecy energy efficiency maximization (SEEM) problem for the CBS-CU transmission under the constraints of the transmit power of CBS, the SR of CU and the quality-of service (QoS) requirement of PU. Since the formulated optimization problem with a fractional objective function is non-convex and mathematically intractable, they first converted the original fractional objective function into an equivalent subtractive form, and then developed a method of combining the penalty function and the difference of two-convex functions (D.C.) approach to obtain an approximate convex problem.

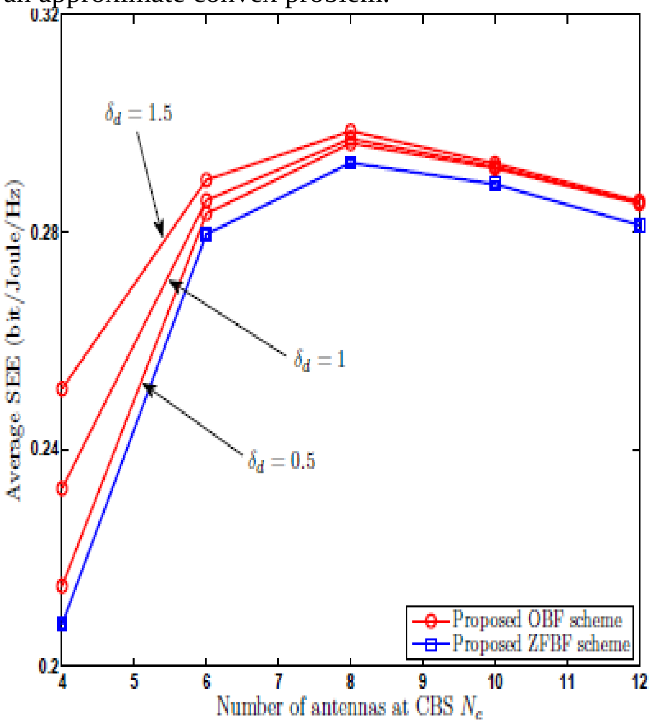

Figure 5: Average SEE versus Nc at CBS with K = 3 and Pmax c = 36dBm [11].

[14] In this paper, they investigated the dynamic channel accessing problem to improve the energy efficiency for a clustered CRSN. Under the primary user's protection requirement, they proposed the resource allocation issues to maximize the energy efficiency of utilizing a licensed channel for intra-cluster and inter-cluster data transmission, respectively. Moreover, with the consideration of the energy consumption in channel sensing and switching, they further determined the condition when sensor nodes should sense and switch to a licensed channel for improving the energy efficiency, according to the packet loss rate of the license-free channel.

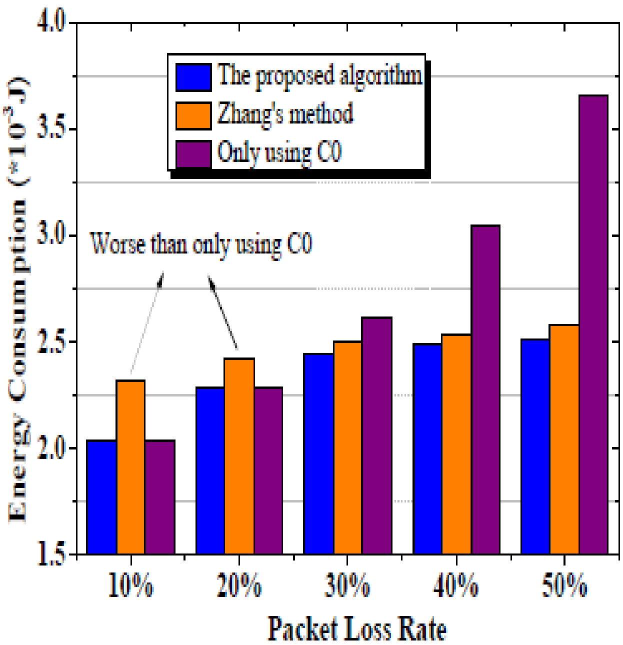

Figure 6: Energy consumption comparison for intra-cluster data transmission under different packet loss rates [14].

IV CONCLUSION AND FUTURE SCOPE

Cognitive radio-based wireless sensor network is the next-generation sensor network paradigm. Important to this emerging sensor network is the need to reduce energy consumption, paving way for 'green' communication among sensor nodes. Although some works have been done for CRNs with cooperative techniques, taking both secrecy and energy performance into account, most of previous works concentrated on SUs with maximizing energy efficiency under the secrecy constraint and vice versa. Therefore, in this paper, we have proposed a survey for the energy efficient, learning-inspired, adaptive and dynamic channel decision and access technique for cognitive radio-based wireless sensor networks.

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