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OFDM-Based Based Cognitive Radio Networks for Spectrum Monitoring Using Energy Ratio Algorithm

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Abstract: This paper presents a spectrum mon- itoring algorithm for Orthogonal Frequency Di- vision Multiplexing (OFDM) based cognitive ra- dios by which the primary user reappearance or availability can be detected during the secondary user transmission. The proposed method or tech- nique reduces the frequency with which spectrum sensing must be performed and greatly decreases the elapsed period between the start of a primary transmission and its detection by the secondary network. This is done by sensing the change in signal strength throughout a number of reserved OFDM sub-carriers so that the availability of the primary user is easily detected. Moreover, the OFDM impairments such as power leakage, Narrow Band Interference (NBI), and Inter-Carrier Inter-ference (ICI) are investigated and their impacts are studied. Both analysis and simulation show that the energy ratio algorithm can e ectively and accurately detect the appearance of the primary user. Furthermore, this method achieves more im- munity to frequency-selective fading channels for both single and multiple receive antenna systems, with a complexity that is approximately twice that of a conventional energy detector.Cognitive radios o er the promise of being a disruptive technologies innovation that would enable the future wireless world. Cognitive radios network is programmable wireless devices that could sense their environment and dynamically adapted their transmission wave- form, channel access methods, spectrum used, and networking protocol as needed for better network and application performance

Keywords: cognitive radio network, orthogonal frequency division multiplexing (OFDM), multi- ple input multiple outputs (MIMO), energy ratio algorithm.

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I. INTRODUCTION

Nowadays, static spectrum access is the main pol- icy for wireless communications. Under this pol- icy, xed channels are assigned to licensed users or primary users for special use while unlicensed users or secondary users (SUs) are prohibited from accessing those channels even when they are un- occupied. The idea of a cognitive radio was de- veloped in order to achieve more e cient utiliza- tion of the RF spectrum. One of the main ap- proaches utilized by cognitive networks is the in- terweave network model in which secondary users seek to opportunistically use the spectrum when the primary users are idle. Primary and secondary users are not allowed to operate simultaneously. In this method, secondary users must sense the spectrum to identify whether it is available or not prior to communication. If the PU is idle, the SU can then use the spectrum, but it must be able to detect very weak signals from the primary user by monitoring the shared band in order to quickly va- cate the occupied spectrum. During this process, the CR system may spend a long time, known as the sensing interval, during which the secondary transmitters are dumb while the frequency band is sensed. Since the CR users do not utilize the spectrum during the detection time, these periods are also called quiet periods (QPs). In the IEEE 802.22 system, a quiet period consists of a series of consecutive spectrum sensing period using energy detection algorithm to determine if the signal level is larger than a prede ned value, which indicates a non-zero probability of primary user transmission. The energy detection is followed by feature detec- tion to distinguish whether the source of energy is a primary user or noise or some disturbance. This mechanism is repeated periodically to monitor the spectrum. Once the PU is detected, the SU aban- dons the spectrum for a nite period and select another valid spectrum band in the spectrum pool for communication. If the secondary user must periodically stop communicating in order to de- tect the emergence of the PU, two important ef- fects should be studied. During quiet periods, the SU receiver may lose its synchronization to the SU transmitter which causes an overall degrada- tion in the secondary network performance. This is a problem when the radical communication tech- nique is sensitive to synchronization errors as in OFDM. The throughput of the secondary network during sensing intervals is minimized to zero which degrades the Quality of Service for those real-time applications like Voice over IP (VoIP). The impact becomes more severe if the duration of the sens- ing intervals is too large as the average throughput of the secondary network becomes very low. On the other hand, if this duration is too small, then the interference to the primary users is increased since spectrum sensing does not provide informa- tion about the frequency band of interest between consecutive sensing intervals.

II. CONVENTIONAL SYSTEM

In this area, there have been researching e orts which attempt to reduce the time duration for spectrum monitoring by jointly optimizing the sensing time with the detection threshold. The primary user throughput statistics are considered to prevent the primary user while the sensing time is minimized. In conventional systems, tradi- tional spectrum sensing is applied once before the SU communication and is not be repeated again unless the monitoring algorithm indicates that a primary signal may be present in the band. If monitoring determines correctly that there is no primary signal in the band, then the time that would have been used performing spectrum sens- ing is used to deliver packets in the secondary network. Therefore the spectrum e ciency of the secondary network is improved. If spectrum monitoring identi es a primary signal in the band during a time period in which spectrum sensing would not have been scheduled, then the disrup- tion to the primary user can be terminated more quickly and hence the e ect of secondary commu- nications on the primary user is reduced. Based on this description, the SU receiver should follow two consecutive phases, specially sensing phase and monitoring phase, where the former is applied for a prede ned period.

III. PROPOSED SYSTEM

Yet, another approach is utilized where the spec- trum is monitored by the CR receiver during the reception and without any quiet periods. The idea is to compare the bit error count, that is produced by a strong channel code like a Low-Density Par- ity Check (LDPC) code, for each received packet to a threshold value. If the number of detected errors is above a certain value, the monitoring al- gorithm shows that the primary user is active. The threshold is obtained by considering the hypothe- sis test for the receiver statistics when the primary signal is absent and the receiver statistics for the desired Secondary-to-Primary power Ratio (SPR). Although this technique is simple and adds almost no complexity to the system, the receiver statis- tics are subject to change by changing the system operating conditions. In real systems, there are many parameters that can a ect the receiver er- ror count such as RF impairments including Phase Noise (PN), Carrier Frequency O set (CFO), Sampling Frequency O set (SFO) and NBI. The er- ror count will depend not only on the presence of a primary signal but it will also depend on the characteristics of those impairments. Also, the receiver statistics may change from one receiver to the other based on the residual errors gener- ated from estimating and compensating for di er- ent impairments. Since it is di cult to character- ize the receiver statistics for all CR receivers, it is better to devise an algorithm that is robust to syn- chronization errors and channel e ects. OFDM is a multi-carrier modulation technique that is used in many wireless systems and proven as a reliable and e ective transmission method. For these rea- sons, OFDM is used as the physical layer modula- tion technique for di erent wireless systems includ- ing DVB-T/T2, LTE, IEEE 802.16d/e, and IEEE 802.11a/g. Similar to other wireless networks, OFDM is mostly used for cognitive networks and has been already in use for the current cognitive standard IEEE 802.22. On the other hand, OFDM systems have their own challenges that need spe- cial treatment. These challenges consist of its sen- sitivity to frequency errors and the large dynamic range of the time domain signal. Moreover, the nite time-window in the receiver DFT results in a spectral leakage from any in-band and narrow band signal onto all OFDM sub-carriers. The tra- ditional spectrum monitoring techniques, that rely on the periodic spectrum sensing during quiet pe- riods, apply their processing on the received time domain samples to nd out a speci c feature to the primary user. Further, it is totally encouraged to remove the quiet periods during the monitoring phase in order to improve the network throughput. In fact, the signal construction for the secondary user can assist the spectrum monitoring to happen without involving QPs. When the secondary user used OFDM as the physical transmission technique, a frequency domain based approach can be adopted to monitor the spectrum during the cog- nitive radio reception only if the secondary user transmitter adds an additional feature to the or- dinary OFDM signal. In this paper, we propose a spectrum monitoring technique, namely the en-ergy ratio (ER) technique, which is mostly used for OFDM based cognitive radios for their operation. Here, the transmitter helps this frequency domain based spectrum monitoring approach by introduc- ing scheduled null tones by which the spectrum can be monitored during cognitive radio reception. This monitoring technique is designed to detect the reappearance of the primary user which also uses OFDM technique. Here, di erent signal chain impairments due to CFO, SFO and NBI as well as frequency selective fading channels are taken into consideration. The technique operates over the OFDM signal chain and hence, it does not require to wait for the decoded bits. This implies a fast re- sponse to PU appearance. Furthermore, the most important OFDM challenges for cognitive radios like power leakage are analysed and their e ects on the proposed monitoring technique are consid- ered. When the secondary user utilizes OFDM as the physical transmission technique, a frequency domain based approach can be employed to mon- itor the spectrum during the CR reception only if the SU transmitter adds an additional feature to the ordinary OFDM signal. In this paper, we propose a spectrum monitoring technique, namely the energy ratio (ER) technique, that is suitable for OFDM-based cognitive radios. Here, the trans- mitter helps this frequency domain based spec- trum monitoring approach by introducing sched- uled null- tons by which the spectrum can be mon- itored during CR reception. This monitoring tech- nique is designed to detect the reappearance of the primary user which also uses OFDM technique.

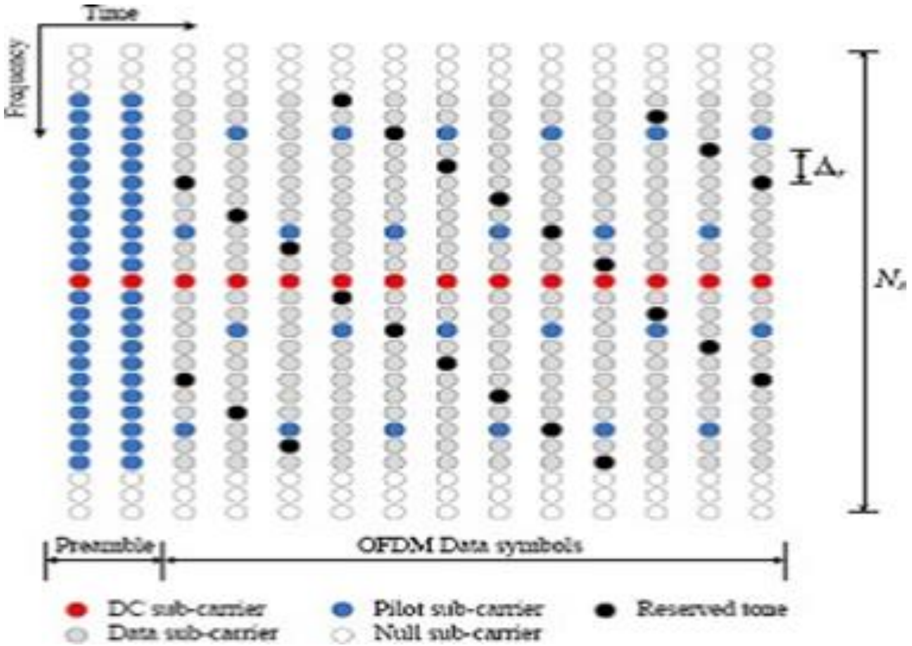

FIGURE 1.
TIME-FREQUENCY ALLOCATION FOR ONE OFDM FRAME TO EXPLOREDIFFERENT SUB-CARRIER TYPES

IV. CONCLUSION

We proposed a spectrum monitoring algorithm that can sense the reappearance of the primary user during the secondary user transmission. This algorithm named "energy ratio" is designed for OFDM systems such as Ecma-392 and IEEE 802.11af systems. For computational complexity, the energy ratio architecture is investigated where it was shown that it requires only about double the complexity of the conventional energy detec- tor. When frequency-selective fading is studied, the energy ratio algorithm is shown to achieve good performance that is enhanced by involving SIMO or MIMO systems. Therefore, our pro- posed spectrum monitoring algorithm can greatly enhance the performance of OFDM-based cogni- tive networks by improving the detection perfor- mance with a very limited reduction in the sec- ondary network throughput.

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