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Stand-alone Architecture for Spectrum Sensing in Cognitive Radio Networks for Smart Buildings

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Abstract. Opportunistic access of the unused frequency bands across the licensed radio spectrum is currently being considered as a means to reduce the spectrum shortage. Cognitive radio is the key technology to implement opportunistic access of spectrum. Due to the unlicensed access, we need to implement certain safeguards so that the unlicensed users do not interfere with the ongoing operations of the licensed users. Spectrum sensing is one of the various issues in cognitive radios in which the unlicensed (secondary) user has to sense the licensed band. In this paper, we separated the spectrum sensing task from the secondary user for the opportunistic spectrum access in the smart building environment. Separate sensing devices are required to be installed in the buildings. The responsibility of these sensing devices is to sense the activity of licensed users, to authenticate the secondary users inside the building and exchange information about the primary user activity with secondary user. Secondary user is free to transmit when spectrum is not being utilized by licensed user without taking care of the primary user activity. The major advantage of the proposed scheme is that it increases the throughput of the secondary user. The proposed framework also makes network secure by authenticating the secondary users. Simulation results show the effectiveness of the proposed framework.

Keywords-cognitive radios; primary user; spectrum sensing; secondary user;

1. Introduction

Nowadays, wireless networks are regulated by a static spectrum allocation policy. However, an outsized portion of spectrum is used sporadically. Wireless networks have gained enormous success in last decade which results in huge demand of spectrum. In order to meet the growing demands of the licensed band which is already overcrowded, opportunistic spectrum access (OSA) is the best solution. Cognitive radio (CR) is the key technology to deploy opportunistic spectrum access [1]. Only an unused portion of the spectrum or white space can be utilized by a CR user.

The most essential task of CR is to detect licensed user/Primary User (PU); if PU is absent then spectrum is available for cognitive radio user/Secondary User (SU) and is called spectrum hole/white space. The process of PU detection is known as spectrum sensing and is achieved by sensing radio environment [2-3].

Simultaneous transmission and sensing of licensed band is not possible. Therefore, for efficient utilization of spectrum holes as well as to avoid harmful interference with PU, SU has to periodically sense the band every T_p seconds known as a sensing period. PU transmission may be obstructed because SU is unaware of its activity during the sensing period, i.e., until the next sensing moment. Therefore, PU's performance is highly dependent on the sensing period. Maximizing sensing period may increase throughput of SU but may make PU obstructed because PU is not often sensed. From a CR network perspective, SU desires to maximize the sensing period and minimize sensing time [4]. The SU has to properly schedule the sensing period to coexist with PUs. By reducing the sensing time, the SU can achieve higher throughput and less interference with PUs without sacrificing sensing reliability.

In this paper, a stand-alone architecture for opportunistic spectrum access in the smart building is presented. We consider the smart building which has dedicated sensing devices and SUs independent of spectrum sensing as shown in Fig. 1. At the start each SU is authenticated by one of many sensing devices present in the building. A handshake takes place between sensing devices and SU whenever SU wants to transmit. Hence, there is no need for SU to periodically sense the band every T_p seconds. This will result in increase of throughput of SUs. The exact protocol to exchange the information between the sensing device and SU is beyond the scope of this paper. The results are compared with the throughput of SUs with sensing devices.

The remaining paper is organized as follows: Section II highlights the spectrum sensing in cognitive radio networks. The proposed stand-alone architecture for smart buildings is presented in Section III. Section IV presents the simulation results and comparisons with the energy detection as sensing scheme for every SU. Finally, conclusions are presented in Section V.

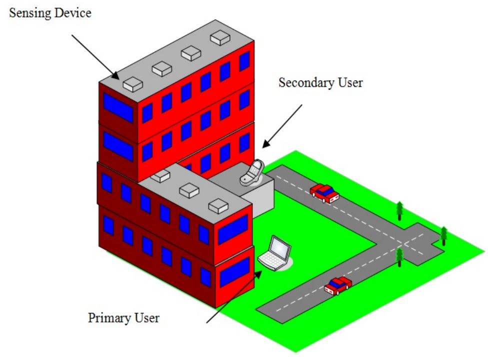


Figure 2. Smart building with stand-alone sensing devices.

2. Spectrum Sensing for Cognitive Radio Networks

Several spectrum sensing techniques have been proposed so far in literature. Major sensing techniques considered for cognitive radios are energy detection, matched filter detection and cyclostationary detection. These techniques are differs with respect to required sensing duration, detection accuracy and complexity [5]. Energy detection and cyclostationary detection are non-coherent detectors however, matched filter requires coherency. Energy detection is the simplest of these techniques and requires less sensing time but it performs poorly under low SNR conditions. On the other hand, cyclostationary detection provides reliable detection but it is computationally complex.

Idea of stand-alone spectrum sensing was initially proposed in [6], they discussed the concept of interference temperature introduced by the Federal Communication Commission (FCC) and proposed a spectrum aware sensor networks. A central controller is assumed to collect sensing information from all sensing devices and inform SUs about spectrum availability.

In [7] authors proposed a distributed stand-alone model for spectrum sensing in which there is no need for centralized controller. The traditional cognitive cycle is compared with the proposed new cognitive cycle.

In our proposed architecture, stand-alone sensing devices are installed in smart building. Sensing devices are responsible for authentication of each SU coming in the building and sensing the activities of PU. Sensing devices and SUs can communicate over control channel for exchanging information about PU. The proposed architecture will improve throughput of SUs inside the smart building.

3. Stand-Alone Architecture for Smart Buildings

We consider a CR network deployment in smart building with N number of SUs. These SUs can transmit on the available licensed channels opportunistically. Fig. 2 (a) shows that in existing architecture, SU has to periodically sense the band every T_p seconds [8]. It is assumed that T_p is priory known to meet the requirements of PU detection.

We propose a stand-alone architecture in which sensing is done by stand-alone sensing devices installed in the building. Sensing devices are continuously monitoring the PU activity and whenever an SU needs to transmit, a handshake takes place between SU and sensing device. There is no need for SU to periodically sense the band to avoid interference with PU. Sensing device interrupts the SU when actual licensed user wants spectrum which is currently under the use of SU and shifts it to some other channel if available. PU detection and interference avoidance is the responsibility of sensing device. The operation of stand-alone architecture is depicted in Fig. 2 (b).

Fig. 3(a) shows that SUs get authenticated by one of the sensing devices when it enters in building. Once authenticated, the probability of spectrum sensing data falsification (SSDF) attacks is almost zero. Any secure authentication protocol can be used here, in our case we used shared key authentication for simulation results. The advantages of authentication have not been considered in this paper. The objective here is to show the increase in throughput of SU. Fig. 3 (b) shows that sensing device is observing the PUs activity and informs SUs about available spectrum over common channel. Energy detection is used to detect PU by all sensing devices inside the building.

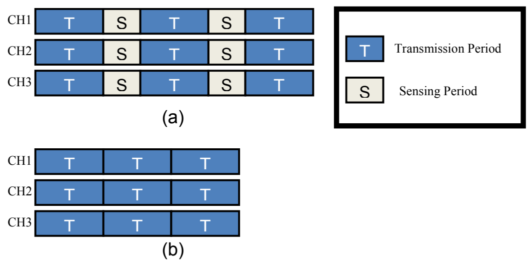


Figure 3. (a) Sensing cycle for existing CR networks (b) Sensing cycle for proposed stand-alone architecture for smart buildings.

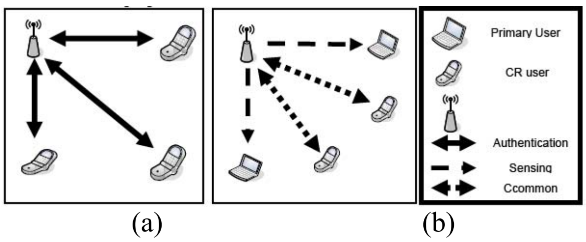


Figure 4. (a) Authentication of SUs (b) stand-alone sensing device is sensing primarily users and information about spectrum hole is shared with SUs.

4. Simulation Results

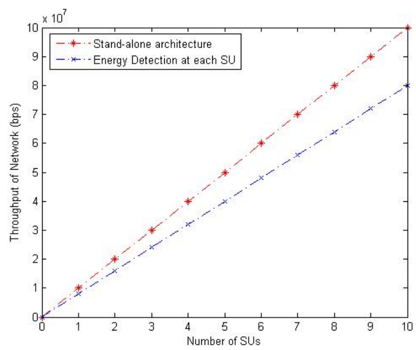
In this section, we compared the throughput of stand-alone architecture and energy detection as spectrum sensing done at each SU. For simulation purpose, we consider ten (10) stand-alone sensing devices with each have energy detection for spectrum sensing. Sensing devices can exchange information with SUs about PU activity on common channel. When SU starts transmitted on available channel its data rate is assumed to be 10 Mbps.

We have considered three cases for energy detection at each SU, in which SU has to sense periodically about PUs activity, a) the transmission period is greater than the sensing period; b) the transmission period is equal to the sensing period and c) the transmission period is less than the sensing period.

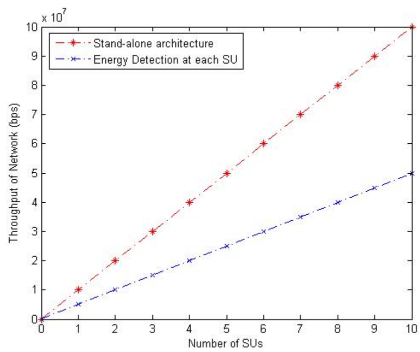
Fig. 4 (a) shows the throughput of the network vs. number of SUs in the network for stand-alone architecture and energy detection at each SU when the transmission period is greater than the sensing period. For simulation purpose, we assume that the transmission time is 4 ms and the sensing time is 2ms. It is depicted that when there are ten (10) SUs in the network, the throughput of the network is increased about 20 Mbps.

Fig. 4 (b) shows the throughput of the network vs. number of SUs in the network for stand-alone architecture and energy detection at each SU when the transmission period is equal to the sensing period. Both the transmission and sensing time are assumed 2ms for this case. It is shown that when there are ten (10) SUs in the network, the throughput of the network is almost increased 100%.

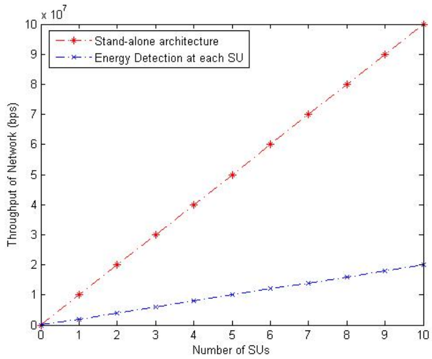
Fig. 4 (c) shows the throughput of the network vs. number of SUs in the network for stand-alone architecture and energy detection at each SU when the transmission period is less than the sensing period. The transmission and the sensing time is 0.5ms and 2ms respectively for this case. It is noted that when there are ten (10) SUs in the network, the throughput of the network is almost increased by five (5) times.



(a)



(b)



(c)

Figure 5. Throughput of the network comparison for (a) the transmission period greater than the sensing period (b) the transmission period equal to the sensing period (c) the transmission period less than the sensing period

5. Conclusion

We analyzed a stand-alone architecture for spectrum sensing in cognitive radio networks for smart buildings. In particular, we used sensing devices in the building and SUs are independent of spectrum sensing to improve throughput of the secondary user network. The proposed stand-alone architecture is compared with the spectrum sensing done by SU in terms of throughput. It is proved by simulation results that the throughput is increased significantly for stand-alone architecture in all cases of interest. Furthermore, it is concluded that mean detection time is zero for SUs in case of stand-alone architecture as SU is not responsible for spectrum sensing.

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