Study and Performance analysis of Dedicated In-Band Control Channels for Cognitive Radio Networks

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ABSTRACT Cognitive Radio (CR) technology provides a smart and optimistic solution to the problem of spectrum scarcity through Dynamic Spectrum Allocation (DSA). Due to the nature of Cognitive Radio Networks (CRNs), where two networks area unit active at the same time, a significant quantity of control messaging is essential in order to coordinate channel access, schedule sensing, and establish release connections. Efficient Control Plane messaging can be achieved by the selection of a suitable Control Channel (CC). This paper provides a comparative study of probable systems for providing reliable channels dedicated to the coordination and information distribution in License-Exempt (LE) bands. This involves determining the potential and limitations of every method.

Keywords -CRN, Control Channels, Spectrum Management, Spectrum Allocation.

I. INTRODUCTION

Due to the anticipated spectrum mobility and therefore the available White Spaces (WSs) are scattered over a huge frequency range in (CRNs), Secondary Users (SUs) essential to exchange a great capacity of control messages in order to promise suitable performance levels [1]. Depending on the target application and the operational mode of the CRN, the role of control messaging can differ significantly and thus a choice should be created on wherever and the way to ascertain the Control Channel (CC) [2].

The CC offers its facilities to dissimilar layers of the CRN protocol stack. This includes the physical layer, network layer, and medium access layer. The functionalities reinforced by a CC include: network self-organization, network coordination, synchronization, cooperation, spectrum sensing and sharing, and flexible data connections [3].

Traditional algorithms assume the availability of a dedicated out-of-band CC [4]. However, different issues arise from such an assumption. First, this solution is expensive due to the need to lease an out of-band channel. Second, there will be some delays in data transmission due to switching RF front-end from an out-of-band CC to the in-band data channel. The majority of the currently proposed CR Medium Access Control (MAC) protocols consider using dedicated CC solutions in licensed bands. For example, MAC algorithms mentioned in [5], [6], and Opportunistic Spectrum MAC (OS-MAC) [7] use a dedicated CC in a band licensed to the CRN for control message exchange. Moreover, the authors in [8] and [9] assume the availability of a dedicated CC. Also, Ultra Wide-Band (UWB) control channel establishment is the focus of different efforts, e.g. [10], [11], where the authors outline the main design and implementation challenges regarding using UWB where information is spread across large bandwidth in an underlay fashion [12].

Even though many researchers have addressed DSA and MAC protocols, little attention was given to the selection and behavior of CCs. Implementing a CC for CRN in License-Exempt (LE) is very challenging due to not being able to reserve a specific channel for this mission. The motivation of this work arises from the need for practical solutions to have reliable CCs for CRNs. These solutions have to be simple enough, yet sophisticated, to be implemented in real-life networks in order to coordinate channel access, schedule sensing, and establish and release connections. Furthermore, most of the works presented in the literature focus on the Data Plane (DP) performance while assuming a perfect exchange of control messages whenever needed, which is not practically the case.

Dedicated in-band CC selection strategies have some advantages that make them a potential solution for the problem in hand. For instance, these schemes are simple to implement and do not require a complex algorithm to be used practically. Also, no switching overhead is required where the CRN chooses one of the Primary Users' (PUs) channels as a dedicated CC. Under this approach, there is no need to look for another CC during communication sessions. In this paper, we focus our study on the performance of CCs that are based on in-band selection strategies. The contribution of this paper is to provide a comparative study on the effectiveness and performance of in-band dedicated CC selection strategies. In addition, we consider a challenging use case of selecting CCs in the License-Exempt (LE) band of 5 GHz, where there is no licensed spectrum to dedicate to CC, and where Long Term Evolution-Unlicensed (LTE-U) is considered for coexistence with Wi-Fi. The proposed LTE-U technology in North America starts transmitting without sensing the channel; hence, it behaves as a PU. On the other hand, Wi-Fi is a typical SU in this context, which backs off when sensing an activity on the channel. Furthermore, to get a realistic insight on the performance of CCs in practical environments, we consider a real-life scenario of an outdoor stadium, which is acknowledged by industrial and standards bodies as one of the most challenging future deployments. Thorough recommendations on the advantages and disadvantages of the selection techniques for CCs are provided as well.

The remainder of this paper is organized as follows: Section II provides details about the network model and the studied environment and scenario. Section III describes the studies selection strategies. Section IV is dedicated to the performance evaluation and interpretation of the investigated CC selection strategies. Finally, the conclusion is given in Section V.

II. NETWORK MODEL

In CRN, the primary network (PN) and secondary network (SN) are considered to be situated in close vicinity and the topology of the PN follows a Homogeneous Poisson Point Process (HPPP) with density of the node is θ_{PU}[13]. For the (SNs), the SUs quantity is fixed for every studied technique. In CRN, The Access Points (Aps) are assumed to be aware of PUs activity, which is likely by employing specific sensing techniques [14].

We studied real-life scenario is an outdoor open-air stadium [15]. The simulated area has 16 APs. The simulated area is divided into blocks where each block has dimensions of 12m X 12m and is served by one AP. SUs' positions are assumed to be fixed and follow the layout of the chairs in stadium design, since people will be sitting in their seats during the show [15], [16]. APs support 4x4 Multiple-Input Multiple-Output (MIMO) with transmission power of 19 dBm. Additionally, the SUs support 2x2 MIMO with transmission power of 15 dBm.

The channels are modeled using the WINNER II B1 Line-of-Sight (LOS) outdoor broadcast model [17]. The channel model of WINNER is a geometry-based stochastic model where the parameters of channel are determined based on statistical distributions extracted from channel measurements.

Shadowing affects the connectivity of the nodes and the standard deviation of the shadowing (s) are in the range of 3 to 12 dB [18]. Moreover, since the correlation of shadowing is of high importance when studying CRNs due to their coexistence with the primary network [19], it is taken into consideration in this work.

In order to decrease the collision rate in the CRN, the time slots used at SN for packet transmission by SU. The traffic of the communication movements of PUs and SUs are modeled as Bernoulli arrival processes with parameters λ_{PU} and λ_{SU}, respectively [20]

III. SELECTION STRATEGIES

The selections approaches of dedicated in-band CC should be characterized into interweave and underlay. In the interweave approach, when the PU regains the channel, the CRN will refrain from using this channel as CC and consequently the whole communication session will be put on hold. This process may be repeated as many times as needed.

On the other hand, in underlay setting, the transmission power is set to 1/3 of the transmission power in interweave setting. Also, the CRN will be using the dedicated CC at all times even if a PU becomes active on this channel.

IV. SIMULATION RESULTS

We can use to calculate the performance of studied approaches by the parameters like success percentage (Psuccess) beside with the achieved control messages throughput. Psuccess is well defined as the probability that SUs with control messages succeed in accessing the CC. The attained throughput is calculated by averaging the data rate of the control messages flow for 1000 simulation runs. The data rate is the number of actual bits transmitted over the WINNER II channel model per unit time when a SU succeeds in accessing the CC. Lastly, we assume a Packet Drop Ratio (PDR) of 5%. The correlation of the shadowing map is set to 1/20 and the number of PUs is set to 50 and their communication activity (λPU) is set to 0.5, unless stated otherwise.

As the range of SUs will increase, the performance of these choice criteria degrades quickly. This is often as a result of the inflated competition to access the CC once the SU range of SUs will increase. However, the success rate is 98%, once the amount of SUs is 50 and λSU is about to 0.1. the rationale behind this is often that SUs generate management messages at a coffee rate and thence the CC are ready to accommodate all of the fifty SUs throughout the days of getting the CC vacant from any PUs activity (figure 1).

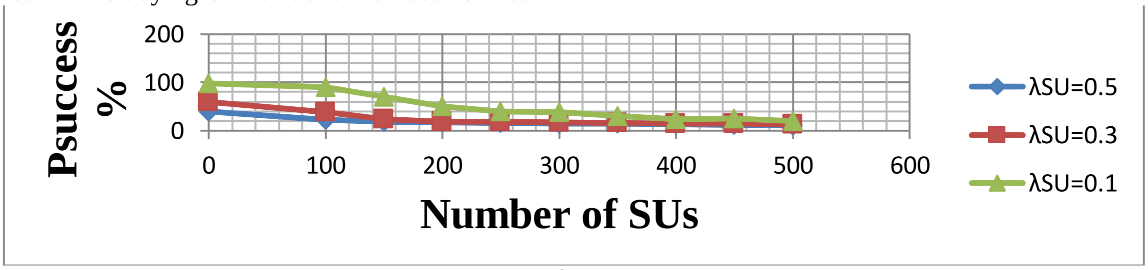

Fig 1:probability of success vs. more SUs

Moreover, the system remains ready to succeed successful rate over 50% of range when the number of SUs is 200 and λSU is 0.1. The decrease within the success rate is thanks to the magnified range of mammal genus that conceives to access the CC. In figure 2, the attained throughput on the CC is in the range between 4 and 4.5Mbps. Because the variety of SUs will increase, the accomplished throughput varies slightly and doesn't increase respectively. This can be because of the accrued competition between SUs to access the CC and therefore the extent of collision and packet loss will increase, which can keep the accomplished throughput nearly at constant level.

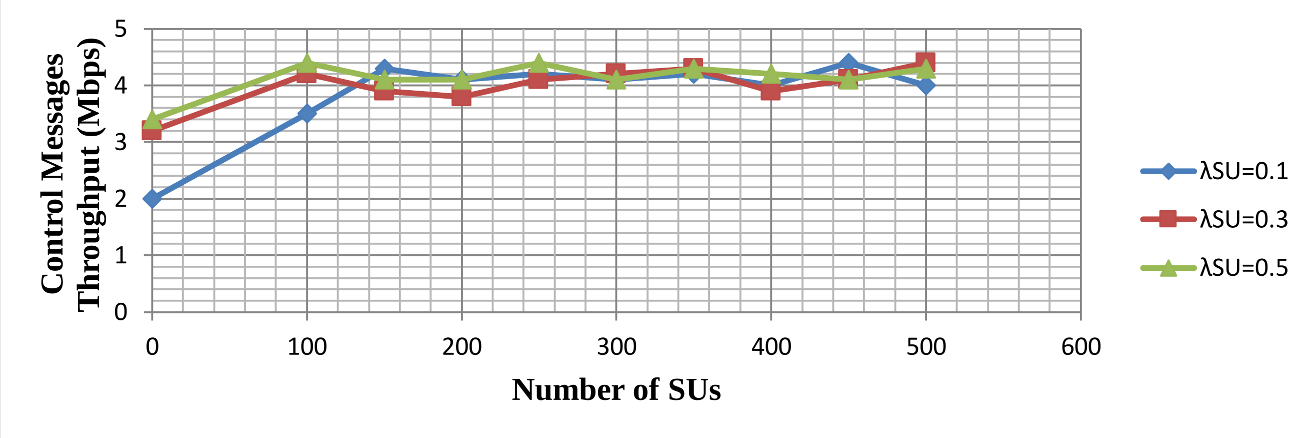

Fig 2: Throughput vs. SUs

V. CONCLUSION

We presented different possible scopes to select an appropriate CC effectively for CRNs. And also investigate the performance of CC selection approach using simulator tool. It can be concluded that interweave selection strategy is a better option when the movement of the primary network is low. So we proposed hybrid approach that will be subject to future validation. Finally, we believe that integrating the CC PU with spectrum allocation algorithms while looking at the whole picture of cognitive radio functionalities will contribute to the success of enabling and deploying CRNs in the near future.

REFERENCES

[1] M. Ibnkahla, Cooperative Cognitive Radio Networks: The Complete Spectrum Cycle. CRC Press, 2014.

[2] P. Pawełczak, S. Pollin, W. So, A. Bahai, R. Prasad, and R. Hekmat, “Performance analysis of multichannel medium access control algorithms for opportunistic spectrum access,” IEEE Transactions on Vehicular Technology, vol. 58, no. 6, pp. 3014–3031, 2009.

[3] Z. Zhang, K. Long, and J. Wang, “Self-organization paradigms and optimization approaches for cognitive radio technologies: a survey,” IEEE Wireless Communications, vol. 20, no. 2, pp. 36–42, 2013.

[4] A. El-Mougy, M. Ibnkahla, G. Hattab, and W. Ejaz, “Reconfigurable wireless networks,” Proceedings of the IEEE, vol. 103, no. 7, pp. 1125–1158, July 2015.

[5] O. Mehanna, A. Sultan, and H. El Gamal, “Blind cognitive MAC protocols,” in IEEE International Conference on Communications (ICC), 2009, pp. 1–5.

[6] A. De Domenico, E. Strinati, and M. Di Benedetto, “A survey on MAC strategies for cognitive radio networks,” IEEE Communications Surveys Tutorials, vol. 14, no. 1, pp. 21–44, 2012.

[7] B. Hamdaoui and K. G. Shin, “OS-MAC: An efficient MAC protocol for spectrum-agile wireless networks,” IEEE Transactions on Mobile Computing, vol. 7, no. 8, pp. 915–930, 2008.

[8] A. Sabbah, “Dynamic spectrum allocation for cognitive radio networks: A comprehensive optimization approach,” Ph.D. dissertation, Queen’s Univesity, 2015.

[9] S. Debroy, S. De, and M. Chatterjee, “Contention based multichannel MAC protocol for distributed cognitive radio networks,” IEEE Transactions on Mobile Computing, vol. 13, no. 12, pp. 2749–2762, Dec 2014.

[10] A. M. Masri, C.-F. Chiasserini, C. Casetti, and A. Perotti, “Common control channel allocation in cognitive radio networks through UWB communication,” Journal of Communications and Networks, vol. 14, no. 6, pp. 710–718, 2012.

[11] M. Petracca, R. Pomposini, F. Mazzenga, R. Giuliano, and M. Vari, “An always available control channel for cooperative sensing in cognitive radio networks,” in IEEE Wireless Days (WD), 2010, pp. 1–5.

[12] B. F. Lo, “A survey of common control channel design in cognitive radio networks,” Physical Communication, vol. 4, no. 1, pp. 26–39, 2011.

[13] A. Sabbah and M. Ibnkahla, “Optimizing dynamic spectrum allocation for cognitive radio networks using hybrid access

scheme," in IEEE Wireless Communications and Networking Conference (WCNC), April 2016, pp. 2033–2038.

[14] G. Hattab and M. Ibnkahla, "Multiband spectrum access: Great promises for future cognitive radio networks," Proceedings of the IEEE, vol. 102, no. 3, pp. 282–306, March 2014.

[15] J. Soder, F. Mestanov, E. Sakai, K. Sakoda, and K. Agardh, "Stadium scenario for High-Effeciency WLAN (HEW)," IEEE 11-14/0381r, March 2014.

[16] B. Bellalta, "IEEE 802.11 ax: high-efficiency WLANs," IEEE Wireless Communications, vol. 23, no. 1, pp. 38–46, 2016.

[17] C. Wijting, K. Doppler, K. Kalliojarvi, N. Johansson, J. Nystrom, M. Olsson, A. Osseiran, M. Dottling, J. Luo, T. Svensson et al., "WINNER II system concept: advanced radio technologies for future wireless systems," in Proceedings of the ICT-Mobile Summit Conference, 2008.

[18] A. Sabbah and M. Ibnkahla, "Integrating energy harvesting and dynamic spectrum allocation in cognitive radio networks," in IEEE Wireless Communications and Networking Conference (WCNC), April 2016, pp. 784–789.

[19] E. B. Greenstein, A. J. Goldsmith, and J. Larry, Principles of Cognitive Radio. Cambridge University Press, 2012.

[20] V. S. Frost and B. Melamed, "Traffic modeling for telecommunications networks," IEEE Communications Magazine, vol. 32, no. 3, pp. 70–81, 1994.