Cooperative Power and Contention Control MAC Protocol in Multichannel Cognitive Radio Ad Hoc Networks

Chien-Min Wu
Dept. of computer science
and information engineering
Chiayi,62249, Taiwan, R.O.C.
Email: cmwu@mail.nhu.edu.tw

Hui-Kai Su
Dept. of electrical engineering
Yunlin,632, Taiwan, R.O.C.
Email: hksu@nfu.edu.tw

I. Extended abstract

Wireless networks are regulated by a fixed spectrum assignment policy and the spectrum is assigned to license holders or services on a long term basis for large geographical regions. The variation range in the utilization of the assigned spectrum is about 15% to 85% with a high variance in time according to Federal Communications Commission (FCC). A new communication technique is proposed to overcome the limited available spectrum and the inefficiency that is to take advantage of the existing wireless spectrum opportunistically. This new networking technique is referred to as NeXt Generation (xG) Networks as well as Dynamic Spectrum Access (DSA) and Cognitive Radio Networks (CRNs)[1], [2], [3].

In CRNs, secondary users (SUs) can opportunistically utilize the spectrum when this spectrum of primary users (PUs) is idle. In cognitive radio ad hoc networks, spectrum can be divided into several channels. One channel can be used by SU when there is no interferences with other SUs and no interferences between the SUs and PUs and this will improve the network performance. In multichannel cognitive radio ad hoc networks, channels are unreliable due to collisions between SUs and PUs. Therefore the medium access control (MAC) protocols are quite important to avoid the collisions between SUs and PUs and to overcome the hidden terminal problems and exposed terminal problems.

The MAC protocol in multichannel cognitive radio ad hoc networks has two approaches. One is centralized and focus on infrastructure-based networks. For this network, the spectrum assignment of SUs is assigned by coordinator. Another is distributed approach and the spectrum allocation is processed by the contention-based channel access policy.

In [4], the authors proposed a hardware-constrained cognitive MAC (HC-MAC) for efficient spectrum management for CRNs and consider sensing constraint and transmission constraints of practical cognitive radios. A decentralized cognitive MAC (DC-MAC) for opportunistic spectrum access in ad hoc networks is proposed in [5]. DC-MAC allow SUs to independently search for spectrum opportunities without a central coordinator and assume SUs may not be able to perform full-spectrum sensing or may not be willing to sensing the spectrum channel when it has no data to transmit.

In [6], the authors proposed a opportunistic spectrum MAC (OS-MAC) protocol for spectrum-agile wireless networks. OS-MAC can adaptively and dynamically search and take advantage of opportunities in the PUs' spectrum and can access and share among SUs and PUs. In [7], a cognitive MAC (C-MAC) protocol for multi-channel wireless networks is proposed. C-MAC, each channel is divided into some superframes. Each superframe contains a slotted beaconing period which can provide the control messages exchange and negotiate channel usage. Each SU sends a beacon in a slot during beaconing period to overcome the hidden terminal problems , channel reservations and mobility.

In [8], the authors proposed an efficient cognitive radio-enabled multi-channel MAC (CREAM-MAC) protocol for wireless networks. In CREAM-MAC, each SU is equipped with a cognitive radio transceiver and multiple channel sensors and can overcome the collisions among SUs and between the SUs and PUs. A MAC protocol for opportunistic spectrum access (OSA-MAC) in cognitive radio networks is proposed by [9]. In OSA-MAC, each SU exchange control informations in a dedicated control channel. OSA-MAC uses the idea from PSM (Power Saving Mechanism) in IEEE 802.11 DCF-based WLANs and assume that time is divided into beacon intervals and all of the SUs are synchronized by periodic beacon transmissions.

In [10], a novel MAC (N-MAC) scheme for multichannel cognitive radio ad hoc network is proposed. N-MAC has three features and their are collaborative opportunistic sensing , transmission power control for PU protection and multiple packet transmission on the reserved channel. In [11], an energy-efficient distributed multichannel MAC protocol for CR networks(MMAC-CR). MMAC-CR can achieve energy-efficient communication and sensing algorithms has following phases. One is a low-power inaccurance scan and another is a high-power accurate scan.

In [12], a cooperative transmit-power (CTP) estimation in MANETs is proposed. CTP provided a fundamental confidence level for the accuracy of the power estimation and enables the development of techniques for allocating network monitors. CTP proposed a simple, distributed cooperation model for multiple monitors. Even with a small number of cooperating monitors, the accuracy of estimation can be significantly improved.

In this paper, we will propose a Cooperative Power and Contention control MAC (CPC-MAC) protocol in Cognitive Radio Ad Hoc Networks to solve the multichannel hidden terminal PUs and SUs problems and multichannel exposed terminal SUs problem by build appropriate number of monitor nodes in suitable positions.

There are three functions in CPC-MAC. First, SU transmitter sends the RTS frame including transmission power to SU receiver, SU receiver sends CTS frame including receiving power to SU sender. Monitor nodes send position and receiving power to SU sender and SU receiver. SU transmitter selects three monitors that their receiving powers are approach to each other. SU transmitter estimates its position and sending power by deterministic propagation model. This will reduce the interference to hidden PU terminal. Second, the SU in the transmission range of the PU will send one highest priority interrupt frame in control channel to one-hop neighbors of SU to protect the PU. Third, CPC-MAC adds one channel confirm control frame in IEEE CSMA/CA to overcome the exposed SU problem.

We also compare our proposed scheme to the existing IEEE 802.11 DCF and the other MAC protocols in Cognitive Radio ad hoc networks using ns2 simulation tool. We will show that CPC-MAC will improve the system throughput and reduce the energy consumption.

References

[1] I. F. Akyildiz, W. Y. Lee, M. C. Vuran and S. Mohanty, *NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey*, Computer Networks, Vol. 50, 2006, pp. 21272159.

[2] J. Xiang, Y. Zhang and T. Skeie, *Medium access control protocols in cognitive radio networks*, Wireless Communications and Mobile Computing, Volume 10, Issue 1, January 2010, pp. 31-49.

[3] C. Cormio and K. R. Chowdhury, *A survey on MAC protocols for cognitive radio networks*, Ad Hoc Networks, Volume 7, Issue 7, September 2009, pp. 1315-1329.

[4] J. Jia, Q. Zhang, X. Shen, *HC-MAC: a hardware-constrained cognitive MAC for efficient spectrum management*, IEEE Journal on Selected Areas in Communications, Volume 7, Issue 1, 2008, pp. 106-117.

[5] Q. Zhao, L. Tong, A. Swami and Y. Chen, *Decentralized cognitive MAC for opportunistic spectrum access in ad hoc networks: a POMDP framework*, IEEE Journal on Selected Areas in Communications, Volume 25, Issue 3, 2007, pp. 589600.

[6] B. Hamdaoui B and K. Shin, *OS-MAC: an efficient MAC protocol for spectrum-agile ireless networks*, IEEE Transactions on Mobile Computing, Volume 7, Issue 8, 2008, pp. 915930.

[7] C. Cordeiro and K. Challapali, *C-MAC: a cognitive MAC protocol for multi-channel wireless networks*, The 2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks 2007 (DySPAN 2007), April 2007, pp. 147157.

[8] H. Su and X. Zhang, *CREAM-MAC: an efficient cognitive radio enabled multi-channel MAC protocol for wireless networks*, 2008 International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2008), June 2008, pp. 18.

[9] L. Le, and E. Hossain, *OSA-MAC: a MAC protocol for opportunistic spectrum access in congnitive radio networks*, Wireless Communications and Networking Conference, WCNC IEEE, April 2008, pp. 1426-1430.

[10] W.S. Jeon, J.A. Han and D.G. Jeong, *A Novel MAC Scheme for Multichannel Cognitive Radio Ad Hoc Networs*, IEEE Transactions on Mobile Computing, Volume 11, No. 6, June 2012, pp. 922934.

[11] M. Timmers, S. Pollin, A. Dejonghe, L.V. Perre, and F. Catthoor, *A Distributed Multichannel MAC Protocol for Multihop Cognitive Radio Networks*, IEEE Transactions on Vehicular Technology, Volume 59, No. 1, January 2010, pp. 446459.

[12] I.W.H. Ho, B.J. Ko, M. Zafer, C. Bisdikian, and K.K. Leung, *Cooperative Transmit-Power Estimation in MANETs*, WCNC IEEE, March 2008, pp. 2241 - 2246 .