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Contribution to Working Group WG3/Special Interest Group SIG3
WG3 - Definition of network-wide mechanisms for enabling the cognitive
SIG3 - Mobility management for cognitive wireless networks

Title: Improved Bootstrapping Approach in Multichannel Cognitive Radio Ad Hoc Networks

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The Cognitive Radio Ad Hoc Networks (CRAHNs) represent an existing paradigm in wireless communications. According to [1], CRAHNs need in addition to the communication stack further important components. These are the Channel Allocator, Mobility Manager, and Admission Control Manager. With this paper, we address the first component – the Channel Allocator and specifically the establishing of a so called common control channel (CCC) during the bootstrapping phase of the network deployment. This enables neighboring Cognitive Radios (CRs) to cooperate by exchanging spectrum-sensing and cross-layer control information. With our solution, we seek to support a fast network deployment with efficient establishment of a CCC, untethered mobility, and self-organized network management.

In our previous work [2], we introduced a Distributed Consensus Algorithm to address the problem of distributed CCC allocation in CRAHNs. Our solution defines token ring architecture for the CCC and introduces an additional feature, the token-embedded pilot-tone, used by the consensus algorithm to derive a channel quality metric. The performance of the Distributed Consensus Algorithm has been evaluated through simulations where different network scenarios have been used. The results show a significant increase of network capacity and spectrum efficiency when compared to a sequence-based rendezvous scheme.

The main idea of the Distributed Consensus Algorithm can be briefly described as follows. Each CR represents a selfish agent that seeks to agree with its neighbors on a CCC relying only on locally available information. To provide a decision-making criterion for each CR, a distributed utility function is being used – a channel quality indicator (CQI). The CQI is an average sum of all link capacities established between a given CR and the set of its network peers that are present on a given channel. CQI depends on the location of the CR, and on the spatial distribution of neighboring CRs, interference sources, and noise at the time of the measurements. For a given set N_j of ring-participating CRs, accessing a time-continuous channel of finite bandwidth B, the CQI measured by CR j is

$$\mathrm{CQI}_{\mathrm{j\ previous}} = \frac{\mathrm{B}}{|\mathrm{N_j}|} \sum_{n \in \mathrm{N_j}} \log_2(1 + \mathrm{SINR}_{nj})$$

The results obtained through simulations show that the proposed Distributed Consensus Algorithm significantly increases the spectrum efficiency of CCCs in CRAHNs, and achieves spatially self-organized CRs clustering without geo-location metadata, which can potentially lead to benefits in terms of spatial reusability of spectrum resources.

In this work, we present an improvement of the utility function introduced above. The basis for the improvement was a drawback of our previous scheme that has been observed during the evaluation. CQI value reflects the capacity of the links between the given CR and its network peers considering uninterrupted communication scenario. But, since CRs take turns within the token ring network, the utility function must reflect the amount of nodes that share the same token. A new CQI value will be then

$$\mathrm{CQI}_{\mathrm{j\ new}} = \frac{\mathrm{CQI}_{\mathrm{j\ previous}}}{\mathrm{N_j}} = \frac{\mathrm{B}}{\mathrm{N_j^2}} \sum_{n \in \mathrm{N_j}} \log_2(1 + \mathrm{SINR}_{nj})$$

Using the setup from our previous work in [2], we introduce in Fig.1 a comparison of the simulation results obtained for the previous and new utility functions in form of the improvement of spectrum efficiency Δ which is defined as

$$\Delta = \frac{\eta_{new} - \eta_{previous}}{\eta_{new}} \ [\%]$$

Using C_{net} as a total network capacity, M as a number of spectrum opportunities occupied by the network, and B as a bandwidth of each spectrum opportunity, we define spectrum efficiency as

$$\eta = \frac{\mathrm{C_{net}}}{\mathrm{M \cdot B}} \ [\mathrm{bps/Hz}]$$

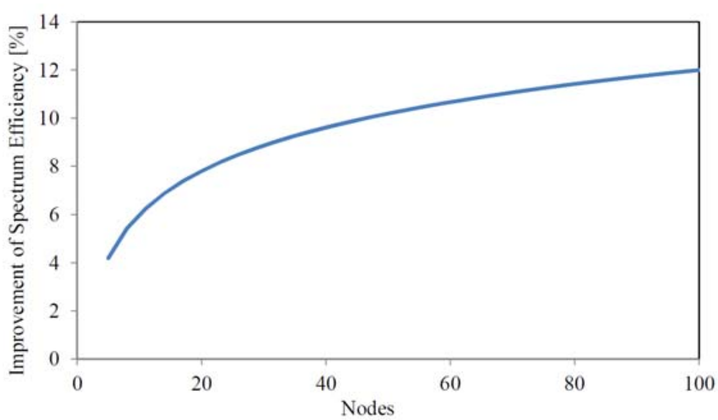

Fig.1. Improvement of spectrum efficiency

References

[1] M. Ergen and D. Lee, “WTRP-wireless token ring protocol,” IEEE Transactions on Vehicular Technology, vol. 53, no. 6, pp. 1863–1881, 2004.

[2] Paulo M. R. dos Santos, Mohamed Abdrabou Ahmed Kalil, Oleksandr Artemenko, Anastasia Lavrenko, Andreas Mitschele-Thiel: "Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks", 2013 IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications: Mobile and Wireless Networks, London September 2013