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Title: Sensing strategies in cognitive radio networks: optimization and ramifications on routing

Abstract: The motivation behind cognitive radio networks (CRNs) was to increase the utilization of the underutilized wireless spectrum bands. An important factor to achieving this goal is fast sensing, because if the cognitive radio (CR) node has one transceiver for sensing and transmission, then the longer the sensing time, the less the transmission time left and the lower the wireless spectrum band utilization. On the other hand, in CRNs, licensed users, also called the primary users (PUs), allow CRs to use their licensed spectrum bands provided that no harmful interference to the PUs occurs. Since there is no cooperation between the PU and the CR node, the CR node should perform periodic sensing (monitoring) to avoid interfering with the PU for more than the maximum PU's tolerable interference delay (TID). If a PU is sensed to be active, the CR node should perform out-of-band sensing (search) to find an available channel. Fast search enhances the CR node's quality of service because the CR node does not need to stop long time due to the PU appearance.

To avoid harmful interference to the PUs, monitoring and searching should be reliable enough. Higher reliability requires more accurate sensing which is achieved by using more sensing time, which leads to decreasing spectrum utilization. Therefore, there is a tradeoff between the detection speed and the reliability of sensing.

In this thesis, we study this tradeoff and propose strategies to optimize the monitoring time which is the periodic sensing time required to protect the PU from interference. Also, we optimize the search time which is the time until finding an available channel to be used by the CR nodes. In addition, we introduce a framework for cooperative in-band sensing (monitoring) that allows multiple CR nodes to share a channel, such that the channel utilization is enhanced and the sensing efficiency is increased. We propose a new definition of sensing efficiency, which is the ratio of the size of transmitted data in one cycle to the size of the data that can be transmitted in the same cycle if there is no need for sensing.

Sensing in CRNs is a key enabling functionality for the reasons mentioned above, as well as because most other functionalities in CRNs are dependent on sensing. Therefore, any function in CRN must consider sensing. Consequently, we propose a spectrum decision framework that can be used by existing routing protocols in order to enhance the throughput of a given end-to-end path, and to increase the probability of finding an end-to-end path.

In addition, we propose a cross layer routing protocol which has cooperation between the network and physical layers. Network layer finds the relay nodes jointly with the channels to be used on each hop, based on spectrum availability information which is generated by the physical layer. Both the spectrum decision framework and the cross layer routing protocol consider the monitoring time overhead of the channels, and generate recommendations to the physical layers of some CR nodes in order to sense some certain channels to enhance the quality of the selected route. The proposed routing protocol enhances the throughput and the stability of the paths, and finds a path with high probability.

We did extensive simulation: first, we show that the proposed framework of in-band achieves better sensing efficiency than the approaches which require periodic in-band sensing. Second, monitoring time optimization

and search time optimization results appear fast due to the convexity of the formulations, and the time of monitoring and search is less when we relax the false alarm probability while protecting the PU. Third, the proposed spectrum decision achieves enhancement to existing routing protocols as high as 100%. Finally, the proposed routing protocol achieves better stability and throughput than existing routing protocols and increases the probability of finding a path.