ABSTRACT

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Due to the temporal and spatial underutilization of licensed spectrum bands, as well as the crowdedness of unlicensed bands, a new spectrum access paradigm has been recently proposed namely, Cognitive Radio (CR). CR enables users to adjust their transceivers' frequencies depending on the availability of licensed frequency bands which are otherwise unused by their licensees, called Primary Users (PUs). Thus, unlicensed wireless users, called Secondary Users (SUs) can dynamically and opportunistically access unused licensed bands in order to improve their throughput and service reliability. Whenever the licensed users, or the PUs, become active, SUs must vacate their bands. This dissertation is concerned with the operation of Cognitive Radio Networks (CRNs), and deals with four important problems.

First, a performance model to study heterogeneous channel access in CRNs is presented. In this model, there are two types of licensed channels, where one type has a larger bandwidth, and hence a higher service rate for SUs. Therefore, SUs prefer to use such channels, if available, over channels in the second type which have a lower service rate. SUs may also switch from the second to the first type of channels when they become available, even if their current channels are still available. We also model the SUs' sensing process, and derive several SUs' performance metrics including average waiting time. Numerical results show that our proposed operational model outperforms a baseline model that does not support prioritized access.

Second, we introduce a low overhead scheme for the uplink channel allocation within a

single cell of CRNs operating as Wireless Mesh Networks (CR-WMNs). The scheme does not rely on using a Common Control Channel (CCC). The proposed mechanism is based on the use of Physical Layer Network Coding (PNC), in which two (or three) Secondary Users (SUs) who are requesting uplink channel allocation are allowed to transmit synchronously over a randomly selected channel from a set of available channels, and without coordination. A Mesh Router (MR) which is listening to these transmissions, and is in charge of channel allocation, can detect up to 2 (or 3) requests, on the same channel due to the use of PNC, and replies back with a control packet which contains information about channel assignment. Our proposed mechanisms significantly outperform traditional schemes that rely on using one CCC, or do not use PNC, in terms of channel allocation overhead time.

Third, we also propose to enable SUs to recover their packets which collide with PUs' transmissions when a PU becomes active for two scenarios, based on the received phase shifts. When a collision occurs between an SU and a PU transmitters, the SU's receiver considers the PU's transmission as an interference, and hence, cancels its effect in order to recover its corresponding received packet's signals. Recovering collided packets, instead of retransmitting them saves transmitters' energy. Numerical results show that a high percentage of energy can be saved over the traditional scheme, in which our packets recovery mechanisms are not employed.

Finally, we propose a novel multicast resilient routing approach to select primary and backup paths from an SU source to SUs destinations. Our approach employs a multilayer hyper-graph, in order to model the network, e.g., channels. The primary paths to destination SUs are selected to minimize the end-to-end delay which takes into consideration channels switching latency and transmission delay. To protect the multicast session, we find a backup path for primary path, if feasible, such that these two paths are shared risk hyper-edge disjoint, in order to prevent a concurrent failure for these two paths, when the corresponding PU for this hyper-edge becomes active. Our simulation results show that increasing the number of available channels, increase the number of feasible primary and backup paths, and the maximum path delay decreases almost linearly.