Dynamic spectrum access (DSA) networks are poised to alleviate the spectrum scarcity problem by allowing secondary (unlicensed) users to access the unused spectrum holes in the licensed bands without causing interference to the primary (licensed) user. However, wide scale deployment of these networks have been hindered due to lack of knowledge of the expected performance of these networks in realistic environments. Also, there is a lack of cost-effective solutions for implementing spectrum database systems that these networks are mandated to use.

In this dissertation, we characterize connectivity based on the signal to interference and noise ratio (SINR) model. Using concepts from percolation theory, we show that not all the deployed secondary nodes necessarily contribute towards the network’s connectivity. We identify such nodes and show that even though a node might be communication-visible it can still be connectivity-invisible. The invisibility of such nodes is modeled using the concept of Poisson thinning. The connectivity-visible nodes contribute towards the effective density which we use to characterize connectivity. We present three techniques that maximize connectivity. We show how traditional flooding techniques are not applicable under the SINR; hence, we propose a modified version of probabilistic flooding that uses lower message overhead while accounting for nodes’ outreach and interference. Next, we analyze the connectivity of multi-channel DSA networks and characterize link formation in terms of the available number of channels. We show how invisibility arises due to abundance of channels which we model via thinning probability. This probability is used to derive the conditions under which the network is connected.

As for the system-wide capacity, we derive the bounds for the maximum achievable capacity of a randomly deployed secondary network with finite number of nodes in the presence of primary users. Finding the exact capacity involves solving an optimization problem that shows in-scalability both in time and search space dimensionality. We speed up the optimization by reducing the optimizer’s search space. Using vector quantization, we characterize and partition the quality-of-service (QoS) space of the secondary users into finite number of regions each of which is represented by one QoS index. We implement a 250-dimensional QoS space on an 8-bit microcontroller and show how the mathematically intensive operations can be computed in a shorter time.

To demonstrate the feasibility of low-cost solutions to database-assisted DSA networks, we present and implement a modular DSA architecture that comprises three main components: the RSSI sensing network, the DSA server, and the service engine. The use of modular design for these components allows for transparency, scalability, ease of maintenance in a plug-n-play manner, without requiring any changes to the other components. Moreover, we provide a blueprint on how to use off-the-shelf commercially available software configurable RF chips to build low cost spectrum sensors. Using testbed experiments, we demonstrate the efficiency of the proposed architecture by comparing its performance to a legacy system and show the benefits in terms of resilience to jamming, channel relinquishment on primary arrival, and best channel determination and allocation. We also show the performance gains in terms of frame error rate and spectral efficiency.