Cognitive radios are expected to revolutionize wireless networking because of their ability to sense, manage and share the mobile available spectrum. According to federal communication commission (FCC), temporal and geographical variations in utilization of assigned spectrum range from 15% to 85%. Efficient utilization of the available spectrum could be significantly improved by incorporating different cognitive radio based networks. Challenges are involved in utilizing the cognitive radios in a network, most of which rise from the dynamic nature of available spectrum that is not present in traditional wireless networks. The set of available spectrum blocks (channels) changes randomly with the arrival and departure of the users licensed to a specific spectrum band. These users are known as primary users. If a band is used by a primary user, the cognitive radio alters its transmission power level or modulation scheme to change its transmission range and switches to another channel. In traditional wireless networks, a link is stable if it is less prone to interference. In cognitive radio networks, however, a link that is interference free might break due to the arrival of its primary user. Therefore, links' stability forms a stochastic process with OFF and ON states; ON, if the primary user is absent. Evidently, traditional network protocols fail in this environment. New sets of protocols are needed in each layer to cope with the stochastic dynamics of cognitive radio networks.

In this dissertation we focus on developing routing strategies in cognitive radio networks. Due to the variation of spectrum availability, end to end paths are fragile and adaptability in the medium access layer alone will not provide stable transmission. Accuracy in decision making of routing protocols plays an important role in the performance of the cognitive radio networks as well. We present a comprehensive stochastic framework and a decision theory based model for the problem of routing packets from a source to a destination in a cognitive radio network. We begin by introducing two probability distributions called ArgMax and ArgMin for probabilistic channel selection mechanisms, routing, and MAC protocols. The ArgMax probability distribution locates
the index of the maximum element of an array of random variables. Hence, since the link's stability is random, it points to the most stable link from a set of available links. Conversely, ArgMin identifies the least stable link. ArgMax and ArgMin together provide valuable information on the diversity of the stability of available links in a spectrum band. Next, considering the stochastic arrival of primary users, we model the transition of packets from one hop to the other by a Semi-Markov process and develop a Primary Spread Aware Routing Protocol (PSARP) that learns the dynamics of the environment and adapts its routing decision accordingly. In PSARP the path is constructed step by step based on the localized random decision of each node. Selection probabilities are assigned to each neighbor node and evaluated periodically using the ArgMax probability distribution. The stochastic framework of PSARP is also an appropriate skeleton for building stochastic-based routing protocols for dynamic cognitive radio networks.

Further, we use a decision theory framework to model the problem of routing under uncertainties involved in a cognitive radio network. A utility function is designed to capture the effect of spectrum measurement, fluctuation of bandwidth availability and path quality. A node cognitively decides its best candidate among its neighbors by utilizing a decision tree. Each branch of the tree is quantified by the utility function and a posterior probability distribution, constructed using ArgMax probability distribution, which predicts the suitability of available neighbors. In DTCR (Decision Tree Cognitive Routing), nodes learn their operational environment and adapt their decision making accordingly. We extend the Decision tree modeling to translate video routing in a dynamic cognitive radio network into a decision theory problem. Then terminal analysis backward induction is used to produce our routing scheme that improves the peak signal-to-noise ratio of the received video.

We show through this dissertation that by acknowledging the stochastic property of the cognitive radio networks' environment and constructing strategies using the statistical and mathematical tools that deal with such uncertainties, the utilization of these networks will greatly improve.

Publications:


Cognitive Radio Mesh Networks”, Accepted in Wireless Communication and Mobile Computing journal, June 2013
