Cooperative Spectrum Sensing in Cognitive Radio Networks Using Graph Message Passing

Abstract

Cognitive radio (CR) networks based on *Dynamic Spectrum Access (DSA)* technique is an emerging solution to the problem of inefficient use of current static spectrum allocation process. Spectrum sensing, i.e., detection of a licensed or primary user (PU) is a fundamental and critical step of a CR cycle. In this approach, unlicensed or secondary users (SUs) are allowed to sense the spectrum dynamically, identifying the spectrum holes, and opportunistically utilize it. Localization, i.e., estimation of 2-D/3-D state of a PU is also a useful task in a CR network (CRN). Knowledge about PU location enables several key functionalities in a CRN.

Cooperation among SUs improves the sensing and localization performance in a CRN. However, it is achieved at the cost of complexity, due to their inherent distributed nature and high-dimensionality. Moreover, the achievable cooperative gain in a CRN largely depends on the propagation channel which also increases th complexity in many folds. Good message-passing algorithms over suitable graphical models have been successful for efficiently solving complex, high-dimensional inference problems.

In this research, we explore an approach, based on probabilistic graphical model (PGM), to effectively address some of the challenging issues of cooperative spectrum sensing (CSS) and cooperative localization (CL) in a CRN. Interestingly, the performance of CSS and CL, under different observation models and network structures over fading channels, have not been adequately addressed for low-complexity solutions. Hence, to address the relevant issues, the overall objective has been to develop sum-product algorithm (SPA) and factor graph (FG) based message-passing frameworks for low-complexity realization of aforesaid inference problems in a CRN under different observation models and network structures. The study is focused on cooperative spectrum sensing and localization over Nakagami-m fading channels in a CRN with independent and dependent observations under centralized and decentralized network structures.

Some of the contributions of this research includes: (a) a likelihood ratio (LR) based fusion rule for CSS over independent Nakagami-m fading that leads to low complexity, (b) proposed and developed an SPA based iterative message passing strategy for performance analysis of CSS with correlated observations over fading in a decentralized CR network that avoids multidimensional integration and provides useful sub-optimal solution, and (c) an approximate message passing algorithm for cooperative localization of the PU developed and evaluated with independent measurements over fading. In brief, this dissertation analyses the distributed inference problems, such as cooperative spectrum sensing and localization in a CR network using SPA based message passing over the representative FG. The usefulness of FG and SPA based models in distributed inference problems is analyzed in detail to highlight its low complexity and modularity. Most of the findings and analytical results have been supported by extensive simulations.

Keywords: Cognitive radio network, cooperative sensing, likelihood ratio, decision fusion, Neyman-Pearson criteria, cooperative localization, mean square error, Cramer-Rao lower bound (CRLB), Nakagami-m fading, sum-product algorithm (SPA), factor graph (FG), network message passing.