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Review

Multicasting in cognitive radio networks: Algorithms, techniques and protocols ☆

Junaid Qadir *, Adeel Baig, Asad Ali, Quratulain Shafi

School of Electrical Engineering and Computer Science (SEECS), National University of Sciences and Technology (NUST), Pakistan

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Multicasting is a fundamental networking primitive utilized by numerous applications. This also holds true for cognitive radio networks which have been proposed as a solution to the problems that emanate from the static non-adaptive features of classical wireless networks. A prime application of cognitive radio networks is dynamic spectrum access, which improves the efficiency of spectrum allocation by allowing a secondary network, comprising secondary users, to share spectrum licensed to a primary licensed network comprising primary users. Multicasting in cognitive radio networks is a challenging problem due to the dynamic nature of spectrum opportunities available to the secondary users. Various approaches, including those based on optimization theory, network coding, algorithms, have been proposed for performing efficient multicast in cognitive radio networks. In this paper, we provide a self-contained tutorial on algorithms and techniques useful for solving the multicast problem, and then provide a comprehensive survey of protocols that have been proposed for multicasting in cognitive radio networks. We conclude this paper by identifying open research questions and future research directions.

Contents

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* Corresponding author.
E-mail addresses: junaid.qadir@seecs.edu.pk (J. Qadir), adeel.baig@seecs.edu.pk (A. Baig), 12mseeaali@seecs.edu.pk (A. Ali), 10mscseqshafi@seecs.edu.pk (Q. Shafi).

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1. Introduction

Cognitive radio networks (CRNs), networks of nodes equipped with cognitive radios (CRs), promise to revolutionize modern wireless networks by incorporating intelligence into its core (Akyildiz et al., 2009). CRs have themselves evolved from the concept of software-defined-radios (SDRs) that allowed a network to adapt to network conditions and user requirements in runtime with software changes only. CRs extend this concept to allow a node to observe its environment and to adapt to it through learning and cognition. A major use-case of CRNs is employing '*dynamic spectrum access*' (DSA) to improve the wireless spectrum utilization. DSA has captured the fancy of industry, regulators, and academia as it promises to remedy the problem of inefficient spectrum utilization brought upon by the historical command-and-control approach to spectrum allocation. The main failing of this static spectrum allocation approach, which licensed specific portions of the radio spectrum to specific applications for exclusive usage, became apparent as more and more wireless technologies clamored for any available spectrum. It was observed that while most of the wireless spectrum was licensed, thereby being off-limits for newer innovative technologies that required spectrum as their lifeline, the spectrum was hardly utilized through a quirk of static spectrum policy and licensed user's bursty communication nature. DSA promises to solve this problem of 'artificial spectrum scarcity' by allowing secondary users (SUs) access to the licensed spectrum subject to the condition that it does not cause any interference for the licensed, or the primary, users (PUs).

Multicasting or group communication is a fundamental networking primitive utilized by numerous wireless networking applications. Some envisioned applications include support of multimedia applications (such as video conferencing), file distribution, news or update dissemination (Paul and Raghavan, 2002; Sahasrabuddhe and Mukherjee, 2000). Multicasting subsumes the models of unicast transmission and broadcast transmission in its paradigm by varying the receiver group from the one extreme of a single receiver to the other extreme of all the network nodes as receivers.

Multicasting over wireless networks is a significant but challenging goal in the field of networks, which requires a lot of issues to be addressed like bandwidth, topology, loss of packets, routing, reliability, security issues and quality of service, before it can be deployed. Providing a trade-off between stability, throughput and packet loss with reduced bandwidth requirement and less power consumption is the main aim of multicast in wireless networks (Quinn and Almeroth, 2001). Furthermore, multicasting is challenging in CRNs due to the dynamically changing topology of CRNs. CRNs often have to operate in unknown radio environments, with the topology of a secondary network depending critically on the temporal and spatial aspects of PU arrivals. This can lead to a scenario where the various CRN nodes have a heterogeneous set of channels available. This complicates the problem of multicast as the channel heterogeneity may mean lack of a common channel between neighbors (Akyildiz et al., 2006). More detailed analysis of routing challenges for multi-hop CRNs is provided in Sengupta and Subbalakshmi (2013).

In this paper, we provide a tutorial on the general algorithms, techniques, and protocols that have been proposed for the wireless multicast problem, particularly, with a focus on CRNs. While there are numerous survey articles on wireless multicast (Varshney, 2002), optimization problems in multicast (Oliveira and Pardalos, 2005), algorithm issues in multicast (Winter, 1987), this is the first work that coherently synthesizes necessary background from fields like optimization theory, network coding theory, algorithms, game-theory, machine-learning in the form of unified tutorial and follows it up with a survey of existing work on multicast in CRNs. We also provide a survey of the state-of-the-art in the field of multicast routing in CRNs, and highlight the open research challenges in this area.

Organization of the paper: The rest of the paper is organized as follows. We provide the necessary background on multicasting, including defining basic terminology, various categories of multicasting approaches, and challenges of multicasting in Section 2. We then provide a self-contained tutorial on various algorithms and techniques from diverse fields such as graph theory, network coding, optimization, machine learning, and game theory in Section 3. A detailed survey of multicasting protocols proposed for CRNs is then provided in Section 4, followed by articulation of open research issues and future research directions in Section 5. Finally, this paper is concluded in Section 6.