A mathematical formulation for joint channel assignment and multicast routing in multi-channel multi-radio wireless mesh networks

M. Jahanshahi a,⁎, M. Dehghan b, M.R. Meybodi b

a Department of Computer Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
b Computer Engineering Department, Amirkabir University of Technology, Tehran, Iran

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A B S T R A C T
Multicast routing is generally an efficient mechanism for delivering identical content to a group of receivers. Multicast is also deemed a key enabling service for a wealth of audio and video applications as well as data dissemination protocols over the last-mile backhaul Internet connectivity provided by multi-channel multi-radio wireless mesh networks (MCMR WMNs). Major prior art multicast protocols in these networks center around heuristic or meta-heuristic initiatives in which channel assignment and multicast routing are considered as two separate sub-problems to be solved in sequence. It might even be the case that the solution for either of these two sub-problems is assumed to be preparatively calculated and given as input to the other. Within this perspective, however, the interplay between the two sub-problems would essentially be ruled out from the computations, resulting in sub-optimal solutions for network configuration. The work in this article is targeted at promoting the adoption of cross-layer design for joint channel assignment and multicast tree construction problem in MCMR WMNs. In the proposed scheme, contrary to the existing methods, these two sub-problems will be solved conjointly and an optimal solution is provided. In particular, a comprehensive cross-optimization framework based on the binary integer programming (BIP) formulation of the problem is presented which also addresses the hidden channel problem in MCMR WMNs. We have, as well, conducted an extensive series of simulation experiments to verify the efficacy of the proposed method. Also, experimental results demonstrate that the proposed method outperforms the genetic algorithm and the simulated annealing based methods proposed by Cheng and Yang (2011) in terms of interference.

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1. Introduction

Wireless mesh network (WMN) is an emerging technology primarily aimed at provisioning for wireless Internet access and scalable QoS-aware delivery of heterogeneous traffic over an integrated milieu of both ad-hoc and infrastructure operation modes (Akyildiz and Wang, 2005; Martı´nez and Bafalluy, 2010). A typical deployment of a WMN is comprised of three layers: the highest layer consists of one or more gateways, also referred to as mesh portals, which connects the WMN to wireline Internet and enables the traffic exchange in between the two networks. The middle layer, however, features the mesh routers which form the WMN's backbone and are in charge of managing the traffic flow across the mesh setting. The nodes located at the lowest layer are essentially the network users (mesh clients in WMN's parlance) with limited capability. This level may also consist of several WLANs or cellular networks. Contrary to mobile ad-hoc networks (MANETs), the wireless mesh backbone is usually stationary, and as opposed to wireless sensor networks (WSNs), there is no limitation on the nodes’ power consumption. An indispensable concern in WMNs, however, is to boost the physical layer capacity and to reduce interference, which is normally achieved by equipping each node with a limited number of radios, usually less than or equal to the number of available channels (Ma et al., 2008; Baul et al., 2004). Each node would then be able to transmit and receive data simultaneously through different channels (Gupta and Kumar, 2000; Das et al., 2006; Xu, 2006). Wireless mesh networks operating with multiple channels on multiple radio interfaces are henceforth referred to in this article as MCMR WMNs.

Of the niche areas of application in the context of MCMR WMNs are multicast-based systems such as video conferencing, online games, webcast and distance learning, to name a few. While wireless communication is intrinsically apt for performing multicast routing due to the broadcast nature of the air medium, the inter-channel interference in WMNs plays a key factor in determining the actual data rate achievable for a multicast service.