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i-QCA: An intelligent framework for quality of service multicast routing in multichannel multiradio wireless mesh networks

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ABSTRACT

Multicast routing has brought a revolution by enabling the delivery of the same content to a group of receivers simultaneously. However, multicast routing in multichannel multiradio wireless mesh networks has been proved to be an NP-hard problem. To achieve optimal performance in multichannel multiradio wireless mesh networks the channel assignment strategy plays an important role. In this paper, we present an intelligent Quality of service multicast routing and Channel Assignment (i-QCA) algorithm which solves the multicast tree construction and channel assignment problem conjointly by intelligent computational methods. The multicast tree construction algorithm is based on the differential evolution approach. The channel assignments in prior works are mostly oriented toward heuristic or meta heuristic approaches and hence produce suboptimal results. The proposed algorithm consists of a genetic algorithm based channel assignment strategy and determines a delay, jitter bounded minimal interference lowcost multicast tree. Our experimental results clearly show that the proposed algorithm achieves much better performance as compared to Multi Channel Multicast (MCM) and QoS Multicast Routing and Channel Assignment (QoS-MRCA) algorithm in multichannel multiradio wireless mesh network environments.

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1. Introduction

Wireless mesh network (WMN) [1] has emerged as a new paradigm targeting towards ensuring flawless wireless internet services. In contrast to traditional wireless networks, wireless mesh nodes are generally static in nature and hence power consumption is not a critical issue. Because of these features the main challenge in routing is to minimize the influence of interference. However, introduction of multichannel multiradio (MCMR) [2,3] approach can reduce the influence of interference to a great extent if an efficient channel allocation algorithm is deployed. Hence, QoS [4,5] in MCMR WMN is largely dependent on channel assignment.

Multicast based systems such as video conferencing, online gaming and remote learning are the key applications of MCMR WMN. To exploit the performance of MCMR WMN we need to deploy an efficient channel assignment strategy. Several channel allocation strategies [6–11] are proposed for unicast routing based systems. However, these algorithms are not suitable in the context of multicast routing. Multicast routing in single channel environment is investigated in [12–14]. In recent researches multicast routing problem in MCMR WMNs is considered as a joint problem of multicast tree construction and channel assignment. Thus efficiency of multicast routing in MCMR WMNs is clearly based on how efficiently we solve these two subproblems.

However, the problem of joint multicast routing and channel assignment in MCMR WMN is proved to be NP. Previous works have focused to solve the two subproblems

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sequentially which have produced inefficient solutions. Recently, some works [15–18] have proposed an integrated solution of the two subproblems. Although some advanced works aim to construct the multicast tree based on intelligent computational methods, but the channel assignment is still based on heuristic or meta heuristic approaches. In this paper, we investigate the multicast routing problem in MCMR WMN and propose an integrated solution of the multicast subproblems based on intelligent computational methods. Our joint framework consists of a multicast tree construction based on a little modified differential evolution [19,20] and a channel assignment based on genetic algorithm [21].

1.1. Our contributions

Our key contributions with this paper include:

- We investigate the multicast routing problem in the context of multichannel multiradio wireless mesh networks and propose an intelligent i-QCA algorithm which solves the multicast subproblems conjointly.
- We design an intelligent multicast tree construction algorithm based on a little modified differential evolution. Our channel assignment algorithm is based on genetic algorithm. We also present optimization models for both the subproblems.
- Next, we perform extensive experiments for a number of scenarios corresponding to different multichannel multiradio wireless mesh topologies and compare the performance of i-QCA with the state of the art routing schemes namely QoS-MRCA (QoS Multicast Routing and Channel Assignment) [15] and MCM (Multi Channel Multicast) [16].

2. Related works

This section presents a brief discussion on the previous works.

Jahanshahi and Barmi [22] perform a detailed survey on the multicast routing protocols. Different multicast protocols have been investigated with respect to different types of channel radio associations for WMNs (SCSR, MCSR, MCMR). The authors also offer a comparative study on the MCMR problems considering the joint channel assignment and multicast tree construction. A ring based multicast routing topology is presented in [23]. The paper presents a study on the performance of multicast communication over a ring structure. A detailed study of different multicast transmission mechanisms in IEEE 802.11aa is presented in [24]. The authors evaluate the different mechanisms in IEEE 802.11aa for some given scenarios and present a comparative study.

Cheng and Yang [15] propose a joint approach to solve the QoS in multicast routing along with channel assignment. The authors propose a tree construction algorithm based on genetic algorithm, simulated annealing and tabu search. QoS-MRCA algorithm considers the total channel conflict to estimate influence of interference. This approach measures interference partially, because all the nodes having channel conflict with the current forwarding node may not have active transmissions at that instant. The authors also present a heuristic channel allocation algorithm which is static in nature and hence cannot take advantages from channel diversity. According to the authors' demonstration the GA based QoS-MRCA algorithm performs the best in MCMR WMN environments.

Two deterministic approaches Level Channel Assignment (LCA) and Multi-Channel Multicast (MCM) algorithm are proposed in [16]. Both of the LCA and MCM algorithm consider channel allocation as a separate step from multicast tree construction. Multicast tree construction is based on BFS algorithm which focuses on minimization of relay nodes and hop count. As the channel allocation algorithm is separated from tree construction it cannot work efficiently. Again, MCM and LCA do not assume any delay bound on the multicast tree which is a significant issue in multimedia and real time data transfer. The authors demonstrate through simulation that MCM performs much better than LCA.

A learning automata based algorithm is proposed in [17]. Learning Automata-based Multicast Routing (LAMR) protocol consists of two phases. In the first phase the multicast tree is constructed and in the second phase the determined tree is optimized. In another work Jahanshahi et al. [18] propose a cross layer design for joint optimization of the multicast tree construction and channel allocation problem. The work in [18] is based on Binary Integer Programming (BIP) model. In another work [25], Vaezpour and Dehghan present a multi-objective genetic algorithm based approach to solve multicast problems. The authors use the non-dominated sorting algorithm (NSGA-II) to define the joint multicast tree construction and channel allocation.

In [26], the authors propose a Wireless Closest Terminal Branching (WCTB) algorithm. WCTB considers the dynamic traffic model. The authors formulate the problem using an integer linear programming (ILP) model. But, considering a ILP model without any relaxation bears a severe drawback as it is not scalable to the network size. In [27] also, the authors model multicast throughput optimization in terms of an integer linear programming (ILP) formulation. However, the authors use LP relaxation to provide scalability to the algorithm. Initially channels are assigned greedily by BFS algorithm which is then given as input to the LP model. However, the authors ignore the multicast tree construction problem while channel assignment is taken as the main problem.

Lan and Trang [28] propose a channel assignment algorithm named Minimum interference Multi-channel Multi-radio Multicast (M4) algorithm. M4 works on readily available multicast tree and hence cannot produce the optimal result. A utility-based multicast routing and channel assignment (UBMR-CA) scheme is proposed in [29]. The authors introduce a utility weight metric (UWM) to compute the utility of a link. Based on the computed UWM, channels are assigned to particular links. However, computation of UWM for each link bears a significant overhead and computational time. In [30] a Minimum Number of Transmission (MCMNT) is proposed. The proposed algorithm focuses to minimize the number of packets copied on to different channels in each node. The algorithm

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