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A weight-aware channel assignment algorithm for mobile multicast in wireless mesh networks

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A R T I C L E I N F O

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A B S T R A C T

Wireless mesh networks (WMNs) are one of key technologies for next generation wireless networks. In this paper, we propose a heuristic channel assignment algorithm with weight awareness to support mobile multicast in WMNs. To enhance network throughput, our algorithm is based on the path forwarding weight to perform channel assignment. In addition to non-overlapping channels, partially-overlapping channels are also used in channel assignment. To fully exploit all available channels in channel assignment, we devise a new channel selection metric to consider the channel separation and the distance between nodes. In mobile multicast, the multicast tree structure cannot be fixed due to receiver (multicast member) mobility. The change of the multicast tree structure will result in channel re-assignment. The proposed algorithm is based on a critical-event driven manner to reduce the times of channel re-assignment as much as possible. Finally, we perform simulation experiments to show the effectiveness of the proposed channel assignment algorithm.

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1. Introduction

Wireless mesh networks (WMNs) have emerged as a main technology for wireless broadband internet access due to low cost and ease of deployment (Akyldiz and Wang, 2005; Bruno et al., 2005; Raniwala and Chiueh, 2005). In WMNs, the IEEE 802.11 standard (IEEE 802, 1999) is mostly adopted to perform wireless communication. There are two types of nodes in a WMN: wireless router and mobile station. The wireless routers are interconnected to form a wireless mesh backbone that can assist the multi-hop packet transmissions among mobile stations. To increase the network throughput of a WMN, each wireless router is usually equipped with multiple radio interfaces. It is very important to assign appropriate IEEE 802.11 channels in the radio interfaces of wireless routers in order to reduce the interference among the routers. The channel assignment problem has been proved to be NP-hard (Skali et al., 2007). Therefore, existing schemes employ heuristic algorithms to perform channel assignment. In most of these existing schemes (Subramanian et al., 2008; Ramachandran et al., 2008; Kyasanur and Vaidya, 2006, 2005), their channel assignment algorithms are mainly designed for unicast routing. However, in WMNs, many popular applications (IP television, video/audio conferencing, distribution of software and financial information, etc.) require the support of mobile multicast communication.

In this paper, we propose a new channel assignment algorithm for efficient performing mobile multicast in WMNs. The proposed algorithm considers multiple important factors of the WMN and mobile multicast, which is abbreviated as *CAMF* (channel assignment with multiple factor considerations). The CAMF algorithm has the following characteristics:

1) All available channels (non-overlapping and partially overlapping channels) of a WMN are used in channel assignment. In WMNs, most of existing channel assignment algorithms (Raniwala and Chiueh, 2005; Ramachandran et al., 2008; Kyasanur and Vaidya, 2006, 2005) use non-overlapping (orthogonal) channels only. In the IEEE 802.11b/g based WMN, there are only three non-overlapping channels. While performing channel assignment, it is easy to cause co-channel (same channel) interference among nodes (wireless routers). To avoid many nodes incurring co-channel interference, we exploit all available channels to perform the channel assignment of WMNs. In Rad and Wong (2006) and Naveed et al. (2007), the channel assignment algorithms also consider the partially overlapping channel assignment, but the algorithms are designed for performing the unicast routing of the WMN.
2) The channel assignment sequence follows the magnitude of path forwarding weight. The paths on a multicast tree have different

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forwarding weights. For a path, its forwarding weight indicates the number of multicast members dependent on the transmission of this path. Intuitively, the node on a path with a larger forwarding weight (the larger-weight path) should have a higher channel assignment priority than the node on the path with a smaller forwarding weight (the smaller-weight path). By doing that, the nodes on the larger-weight path can select their respectively preferable channels to reduce possible interference as much as possible. With incurring less total interference on the larger-weight path, more multicast members can successfully receive more multicast packet within a certain time interval. The proposed CAMF algorithm can enhance the network throughput.

3) The channel separation is combined with the distance to quantify the interference effect. In WMNs, many multicast trees may exist concurrently. In addition to the intra-tree interference, the inter-tree interference is also required to be considered in the channel assignment. The intra-tree and inter-tree interference has been considered in the channel assignment literature of the WMN. Unlike the literature, we design a channel selection metric which combines the channel separation with the distance to correctly quantity the effect of the intra-tree and inter-tree interference. With the channel selection metric, each node can select one or more channels with less interference.
4) The receiver (multicast member) mobility is taken into account in the channel assignment. The multicast tree structure may be varied as receivers arrive, leave, or move. In such a situation, it is required to re-perform channel assignment for the new multicast tree. In our proposed algorithm, we adopt a critical-event driven manner to reduce the times of channel re-assignment. Whenever receiver mobility occurs, the affected node first adjusts its contention window size to reflect the receiver mobility. The channel re-assignment is not performed until packet loss occurs in an affected node.

Compared to existing channel assignment approaches of the WMN, the CAMF algorithm additionally considers the path forwarding weight and the receiver mobility in the channel assignment. Due to holding the above two unique characteristic, the CAMF algorithm can make the WMN with both the small interference cost and the large network throughput while performing multicast communication. Finally, we perform simulation experiments to examine the effectiveness of the CAMF algorithm in various performance metrics.

The rest of the paper is organized as follows. In Section 2, we introduce the preliminaries of this paper. Our channel assignment algorithm is presented in Section 3. Section 4 evaluates the performance of our proposed algorithm. Finally, Section 5 concludes this paper.

2. Preliminaries

In this section, we give the WMN and interference models used in this paper. Then, we introduce the available channels of IEEE 802.11. Last, we review related work.

2.1. Network model

The WMN consists of gateways, wireless routers, and mobile stations (Akyldiz and Wang, 2005). As shown in Fig. 1, the gateways connect the wireless mesh backbone with the Internet backbone. For the wireless mesh backbone, it consists of a number of wireless routers. Some of wireless routers serve as access points for mobile stations within their respective coverage areas. Other wireless routers purely act as relay nodes to transmit packets between wireless routers. The mobile stations are the clients of a WMN that can randomly move. The packet transmission of a mobile station is through multiple wireless routers in the mesh backbone, and then via a gateway to the Internet. For the packet transmission from Internet to a mobile station, the packet transmission is via the above route in the opposite direction.

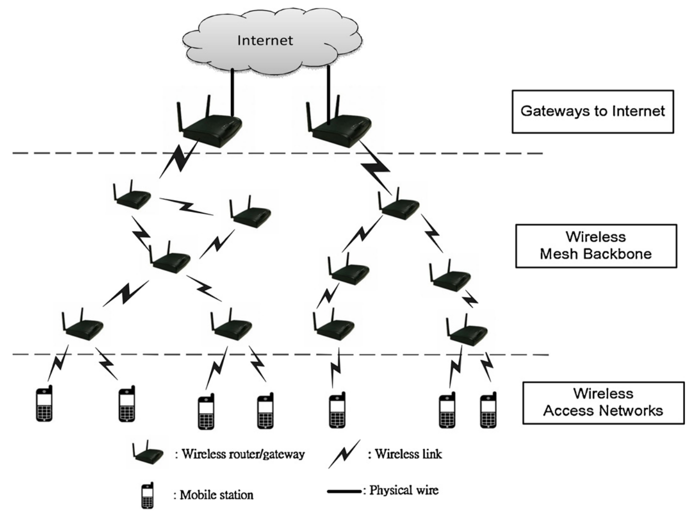

Fig. 1. The system model.

This paper investigates the channel assignment problem for performing the mobile multicast in WMNs. Unlike unicast communication, the multicast communication can concurrently send a packet from a source node to a set of destination nodes (receivers). This communication manner is achieved by establishing a multicast tree. In a WMN, the source node of a multicast tree indicates a gateway. The intermediate nodes of the multicast tree denote the wireless routers located in the backbone of the WMN. The multicast tree is terminated at the wireless routers acting the access point role. As for the receivers of the multicast tree, they are mobile stations. The construction of a multicast tree is a *Steiner tree problem* that is NP-complete (Hwang et al., 1992). In Piechowiak and Zwierzykowski (2012), Bilh and Chou (2012) and Oe et al. (2013), the issue of the multicast routing for WMNs has been also extensively investigated. The simple way to establish a multicast tree is by finding the shortest path from the source node to each of the wireless router with one or more receivers (mobile stations).

2.2. Interference model

The two-hop interference model is usually used in WMNs (Subramanian et al., 2008; Ramachandran et al., 2008). From the node point of view, if node i is within two-hop range of node j, node i is a possibly interfering node of node j. This means that the packet transmission of node j may be affected by node i, and vice versa. Basically, the two-hop interference model is only based on the distance between nodes to estimate the interference relationship. It is a pessimistic model.

2.3. Channels of IEEE 802.11

In WMNs, IEEE 802.11 is a widely used standard for performing wireless communication between wireless routers. In IEEE 802.11, 802.11*a* provides more channels than 802.11*b*/*g*. However, IEEE 802.11*a* has worse penetration depth and a shorter transmission range since it works on a higher frequency spectrum (5 GHz) than IEEE 802.11*b*/*g* (2.4G Hz). In addition, IEEE 802.11*a* has a higher cost in wireless equipment (e.g. access point and interface card). As

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