FPOC: A Channel Assignment Strategy Using Four Partially Overlapping Channels in WMNs

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***Abstrat*—Due to rapid construction and low cost, Wireless Mesh Network (WMN) is one of the most popular technologies in developing wireless network. In WMN, the channel interference and the limited number of available channel affect the network performance. This paper proposed a channel allocation strategy, Four Partially Overlapping Channels (FPOC), to improve the channel utilization in WMN. Based on the link binding and the analysis of the conflict graph, the FPOC mechanism utilizes four channels which are in the lowest interference of all available channels to determine the channel allocation. The numerical results show that our proposed FPOC mechanism improves the network performance by effective utilization of wireless channels over WMN.**

Keywords-Wireless Mesh Network; multi-channel; channel allocation; channel interference.

A. INTRODUCTION

Over the past few years, wireless network has been rapidly developed and accepted as a solution of last hop in Local Area Networks (LANs), such as IEEE 802.11a/b/g standards [1]-[4]. People can connect to Internet via mobile phones, notebooks, Personal Digital Assistant (PDA) or other handheld devices. In order to increase available bandwidth of wireless networks, a new technology (IEEE 802.11n) was proposed. The IEEE 802.11n supports the multi-channel transmission by the multi-radio interface.

Wireless Mesh Network (WMN) is a new technology for constructing wireless network in the ad-hoc mode. The components of WMN are Smart antennas, Dynamic routing router and Security access of Point-to-point architecture. However, due to more and more people connecting Internet via wireless network, the noise interference decreases the performance of wireless transmission. The available frequency spectrum defined in the IEEE 802.11 is from 2.401 to 2.483 GHz [1]. Because of the limited amount of available channel, the problem of the co-channel leads serious signal interference in the IEEE 802.11 wireless network. Accordingly, the previous studies proposed the non-overlapping channel and channel separation mechanisms [5-6] to reduce the signal interference and improve the performance over multi-channel WMN. Moreover, the partially overlapping channel and interference avoidance for each connection links are also proposed to upgrade the channel utilization and system performance. In [7], Ding et al. proposed a channel separation scheme to allocate wireless channel based on the interference distance and weighted conflict graph. But, the interval between the allocated channels is too small so that the problem of channel overlapping still exists. In [8], Liu et al. proposed the Partially Overlapping Channels scheme which allocates channel based on the network traffic load. The disadvantage of the Partially Overlapping Channels scheme is regardless of the channel interference between the links. In [9], Mohammad et al. proposed an Interference Matrix to select firstly the channel which is in the lowest interference of all channels. Due to the lower priority for the channel in the serious interference, the channel interference is not improved after channel allocation.

This paper proposed a channel allocation strategy, Four Partially Overlapping Channels (FPOC), to improve the channel utilization and the system performance in WMN. In the FPOC mechanism, the determination of the channel allocation is based on the link binding and the analysis of the conflict graph. The FPOC mechanism utilizes four channels which are in the lowest interference of all available channels to allocate the wireless channel.

The remainder of this paper is organized as follows. Section II reviews the background and related works about channel allocation over WMN. Section III outlines the proposed FPOC mechanism. Section IV presents the results of a serious simulations designed to compare the performance of the proposed FPOC and related works. Section V provides some brief concluding remarks.

B. RELATED WORKS

A. Channel Overlapping

In [10], Mitch Burton presented the performance analysis of channel overlapping in the IEE 802.11 wireless network, as shown in Fig.1. The notation of *chsp* means the channel separation which is the interval between allocated channels. The notation of *olf* presents the factor of channel overlapping. Based on the analysis results, most of the related studies utilize the wireless channels which the interval (*chsp*) is 5 (i.e. channel 1st, 6th and 11th) and the interference is 0.08%. However, the interferences (*olf*) of 3 and 4 channel interval are 0.54% and 3.75%, which are acceptable for the wireless transmission.

Accordingly, we observed the performance of two channel allocation schemes, including Partially Overlapping Channel and None Overlapping Channel, by the Networks Simulator 2 (NS-2) [11-12]. There are four wireless nodes in the simulation topology, as shown in Fig.2. Each node has two interfaces for transmitting and receiving. Scenario 1 is none overlapping channel (i.e. channel 1st, 6th and 11th) and scenario 2 is partially overlapping channel (i.e. channel 1st, 4th, 8th and 11th).

As shown in Fig. 3, the average throughput of the wireless nodes in the scenario 1 is about 3000 kbps and in the scenario 2 is about 4000kbps. The partially overlapping channel (scenario 2) provides better performance than none overlapping channel (scenario 1) because of the effective utilization of wireless channel. Therefore, this study will propose a channel allocation scheme based on the partially overlapping channel.

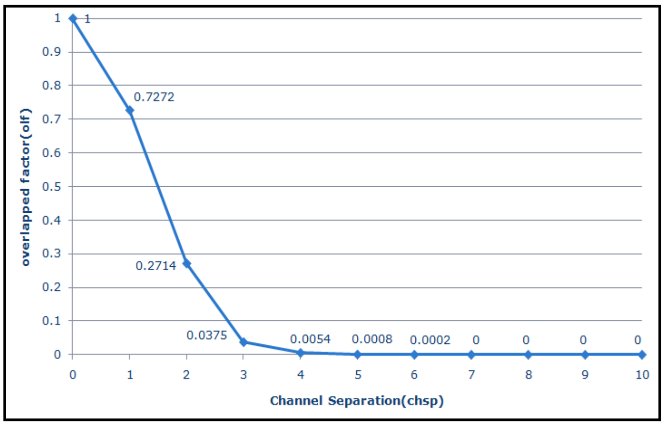

Figure 1. The interference of channel overlapping [7].

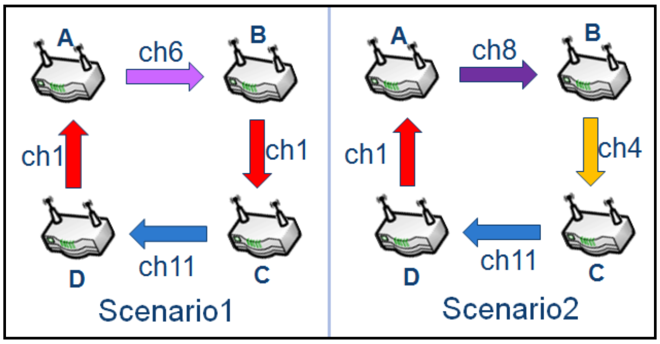

Figure 2. Simulation topology.

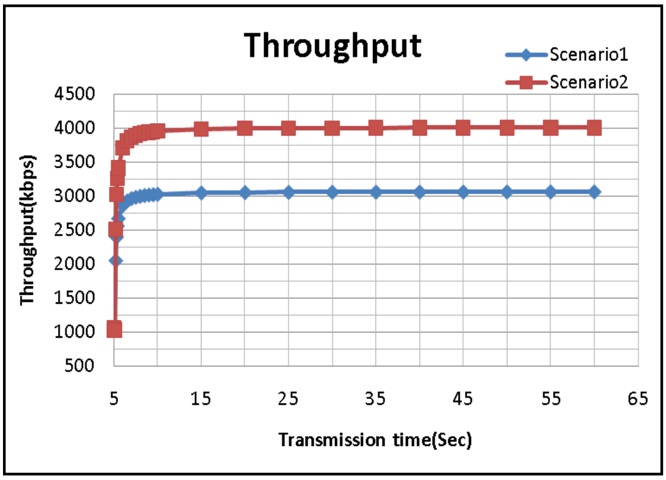

Figure 3. Performance comparison of two scenarios (Throughput)

B. *Greedy Algorithm*

In [7], Yong Ding proposed a Greedy Algorithm to improve the performance of channel allocation in wireless network. The Greedy Algorithm evaluates the distance between two links based on the weighted conflict graph, as shown in Table I. Then, the lowest interference channel will be assigned to the links, as shown in Fig. 4. However, the Greedy Algorithm ignores the traffic load of each wireless interface and cause the unbalance of the allocated channels. Moreover, some of the allocated channels are still overlapping and interfering (channel interval is less than 3) in the transmission range.

Table I. THE RELATION OF DISTANCE AND CHANNEL INTERVAL.

	Channel Separation					
	$chsp_0$	$chsp_1$	$chsp_2$	$chsp_3$	$chsp_4$	$chsp_5$
2M	2R	1.125R	0.75R	0.375R	0.125R	0
5.5M	2R	R	0.625R	0.375R	0.125R	0
11M	2R	R	0.5R	0.375R	0.125R	0

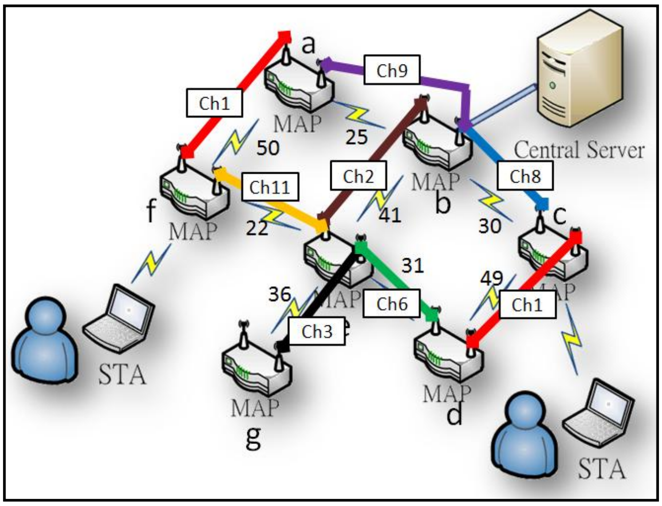

Figure 4. The channel allocation of the Greedy Algorithm.

III. FOUR PARTIALLY OVERLAPPING CHANNELS

FPOC is a centralized channel allocation system. The central server is responsible for network load evaluation and channel allocation. There are three steps in the channel allocation procedure of the FPOC scheme, as shown in Fig. 5. Firstly, the transmission links are assigned to the wireless interfaces by Link Binding. This step aims to balance the load of all wireless interfaces and form the LinkSet which means the links are allocated the same interface and channel. Then, FPOC analyzes the interference of the LinkSet by the Multi-Radio Conflict Graph [13]. Finally, the LinkSet in the most interference will be allocated channel first. Moreover, the LinkSets which are out of interference range to each other could be assigned the same channel to upgrade the channel utilization.

Figure 5. The procedure of channle allocation for FPOC.

A. Link Binding

If the amount of the data links is larger than the wireless interfaces on the MAPs (Mesh Access Points), the interface may serve multiple links by the same channel. The previous researches usually allocate the channel only based on "order" [5]-[9].

In this study, the order of link binding is based on the load of MAPs, which means the MAP with heavier load is given higher priority of link binding. However, even with the higher priority of link binding, the MAPs with heavier load do not be guarantee allocated by the channel in good quality. In our proposed FPOC scheme, before link binding, the order of the link binding for each MAP is determined by

$$order = \frac{Traffic(node) * Link\_num}{hop\_num * Radio\_num} \quad (1)$$

where *Traffic(node)* is the total amount of traffic flow for each MAP, *Link_num* is the total number of one-hop links for each MAP, *hop_num* is the number of hop from the MAP to the Gateway in the shortest path and *Radio_num* is the number of the network interface on the MAP. Based on the Eq. (1), the order of link binding for the MAP is determined shown as Table II.

Table II. THE ORDER OF LINK BINDING

Order	MAP	Order factor
1	MAP_b	144
2	MAP_e	130
3	MAP_c	39.5
4	MAP_a	37.5
5	MAP_d	26.67
6	MAP_f	24
7	MAP_g	6

Based on the Eq. (1), the MAP with heavier load or more links has higher priority of link binding. The traffic load on the MAP will be averagely distributed to the wireless interfaces. As shown in Fig. 6, there are two interfaces (Radio 1 and 2) on the MAP and j links (Link1, Link2, …, Linkj) between the MAP and neighbor MAPs. The links are allocated to the interface and bound as the LinkSet.

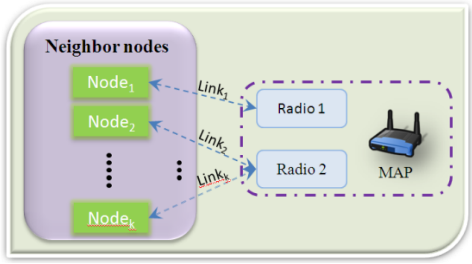

Figure 6. The Link Binding.

B. Link_sets Conflict Graph

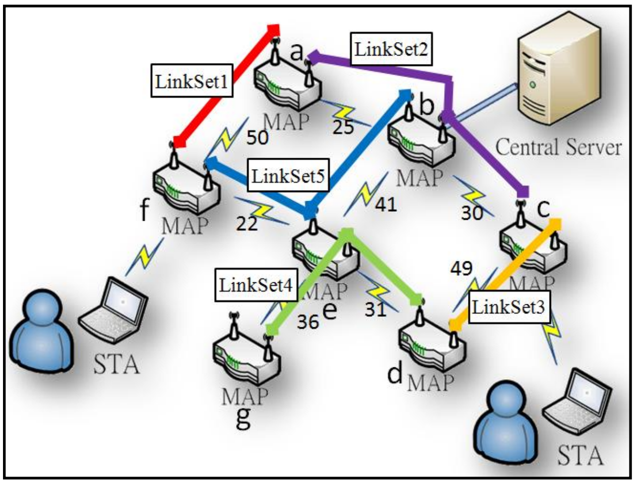

Figure 7. The LinkSet of Link Binding

By the Link Binding, the links using the same interface on the MAP are grouped as a LinkSet and allocated the same channel, as shown in Fig. 7. Then, the conflict of each LinkSet is determined based on the conflict graph. The interference range is assumed as double of transmission rage. The LinkSets are defined as in interference only if the number of hops between the LinkSets is less than three. For example, the none-interference link of the LinkSet1 is the LinkSet3. The conflict graph of the LinkSets in Fig. 7 is presented in Fig. 8.

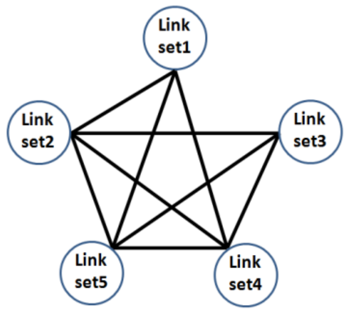

Figure 8. The Conflict Graph of LinkSets.

C. *Channel Assignment*

In order to avoid the interference, the channel allocated to the LinkSet must be free conflict. If there is no free conflict LinkSet, such as LinkSet2, LinkSet4 and LinkSet5, the order of the channel allocation is based on the traffic load on the LinkSet. For example, the LinkSet4 has the higher priority of channel allocation than LinkSet5 and LinkSet2 due to the higher traffic load (67). Next, the LinkSet1 and LinkSet3 are allocated the same channel (Ch11) because of free conflict. The channels allocated to all LinkSets are shown in the Fig. 9 and Table III.

Table III. THE ALLOCATED CHANNELS OF THE LINKSETS

LinkSet	*Conflict-Free LinkSets*	*Traffic*	*Channel*
LinkSet4	Null	67	Ch1
LinkSe5	Null	63	Ch4
LinkSet2	Null	55	Ch8
LinkSet1	LinkSet3	50	Ch11
LinkSet3	LinkSet1	49	Ch11

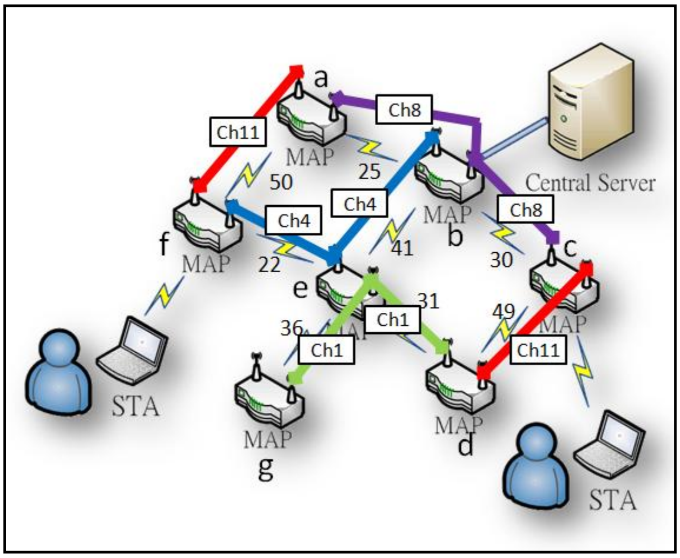

Figure 9. The channel allocation of the FPOC mechanism.

IV. NUMERICAL RESULTS

The proposed FPOC mechanism was verified and compared with the Greed-Algorithm [7] using Network Simulation 2 (NS-2) [11-12]. In the simulations, there are 25 wireless nodes and 2 wireless interfaces for each node. The distance of each node is 200 meter. The transmission rage and interference rage of wireless interface is 200 meter and 440 meter. The MAC protocol is IEEE 802.11 and the data rate is 1 Mbps. There are two flows which are Constant Bit Rate (CBR) in 1 Mbps, as background traffic. The packet size is 1000 bytes.

Fig. 10 presents the variation of throughput for FPOC and Greedy Algorithm. Obviously, the throughput of Greedy Algorithm distributes from 400kbps to 600kbps. The FPOC enhances the performance about 20% of Greedy Algorithm to 800kbps. In the beginning of simulation (t=0~5sec), the FPOC provides a more stable performance of throughput than Greedy Algorithm due to the load balancing for each MAP.

As shown in Fig. 11, the distribution of packet dropped rate for the FPOC is from 0.25 to 0.30, but for the Greedy Algorithm is from 0.28 to 0.32. The FPOC enhances about 4% packet dropped rate of Greedy Algorithm. Accordingly, the numerical results show that our proposed FPOC provides better performance, especially in the beginning of the simulations, by dynamical channel allocating with four channels (channel 1st, 4th, 8th and 11th) which are in the lowest interference and overlapping.

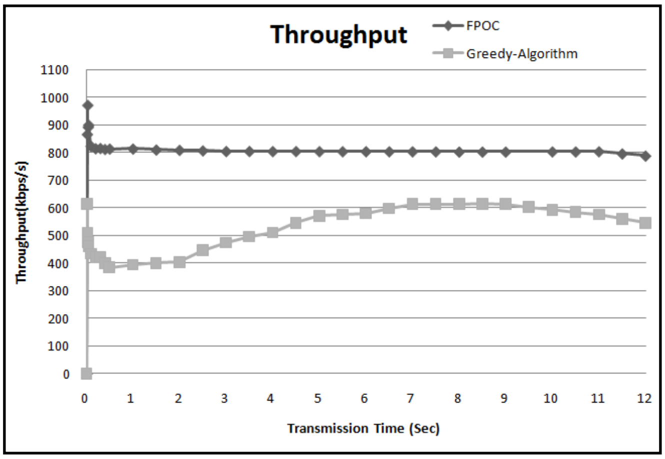

Figure 10. Variation of throughput for PFOC and Greedy Algorithm

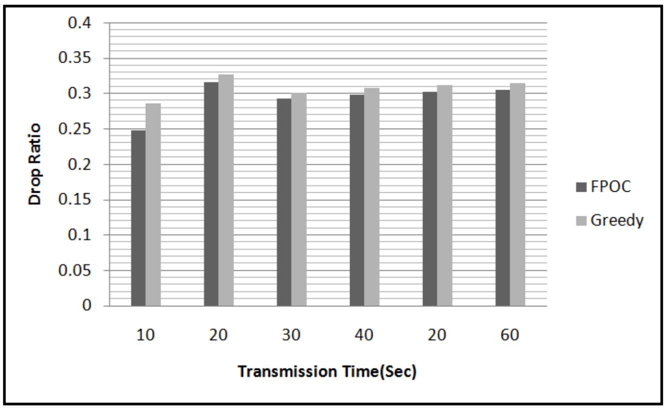

Figure 11. Variation of packet dropped rate PFOC and Greedy Algorithm

V. CONCLUSION

With the rapid growth of wireless network, the wireless mesh network (WMN) extends the transmission coverage for broadband wireless Internet access. However, the transmissions in WMN tend to be interfered by other wireless devices in the same channel. This phenomenon results in packet loss and degrades the performance of WMN. In this paper, we proposed the FPOC mechanism to improve the channel utilization in WMN. The FPOC equally assigns the channels to wireless interfaces by the proposed link binding process. Furthermore, based on the analysis of the conflict graph, the FPOC mechanism could effectively reduce the interference by allocating the lowest interfered channel. The simulation results show that the proposed FPOC mechanism improves the performance in terms of throughput and packet drop rate of WMN network.

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