Recent Trends in Channel Assignment Algorithms for Multi-Radio Multi-Channel in Wireless Mesh Network

Raja Hasyifah Raja Bongsu, Abdullah Mohammed, Mohamad Afendee Mohamed

Abstract: ***Wireless Mesh Networks (WMN) are an attractive technology and has been widely accepted by many organizations due to features such as accessing and routing. The issues regarding capabilities of multi-radio multi-channel (MRMC) has been extensively studied to design an efficient algorithm for WMN. Channel assignment and various techniques have been designed and developed to improve the network performance of MRMC. This paper offers conceptual understanding through a systematic review by classifying channel assignment constraints and its proposed solution. The results from our study provide clear understanding of approaches reported by previous studies in solving channel assignment problem. The analysis offered variety of areas that can be explored in leveraging channel assignment techniques towards improving the network performances.***

Index Terms: channel assignment, multi-radio multi-channel, topology design, wireless mesh network.

I. INTRODUCTION

Wireless Mesh Network (WMN) has been extensively explored on various areas such as design, deployment, and protocols. MRMC has been accepted by many organizations especially in rural network, battlefields and natural disasters, which requires rapid communication network deployment. WMN composes of mesh nodes from gateways, routers, and clients as in Fig. 1. The gateways supply the internet access to small number of mesh routers using wired connections. The mesh routers compose of a mesh of wireless links that act as an access point, serving as an internet gateway for mesh clients. Mesh routers assemble and transmit the traffic generated by the mesh clients. However, mesh routers have minimal mobility. Mesh clients can be either static or mobile. It usually comes with only one radio, and traffic are transmitted by mesh routers to the desired destination.

There are various types of methods and models available in WMN. The traditional WMN is followed the traditional wireless network paradigm known as single-radio single-channel (SRSC) and single-radio multiple-channel (SRMC). SRSC is the simplest topology where each mesh router is equipped with a single radio and all nodes share a single channel. However, some studies discovered that the SRSC suffers from minimal throughput and capacity due to traffic collisions [1]. The performance of SRSC declines drastically with the expansion of the network size [2]. The limitations of SRSC improved by SRMC where multiple channels is used for channel negotiation before transmits a packets [3], but SRMC may not effective to fulfil the network demands such as to support fault tolerance or synchronize neighboring nodes if they want to communicate [2].

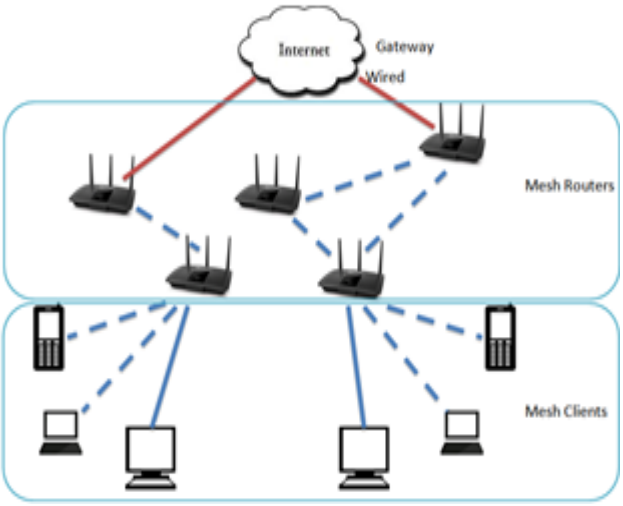

Fig. 1: Fundamental of wireless mesh network architecture

The WMN needs to have a special function to support flexibility to allow user to control their resources. In addition, some algorithm like channel assignment or routing will increased the design complexity of WMN algorithm [4]. Hence, an improvement of SRSC and SRMC which commonly known as multi-radio multi-channel (MRMC) was introduced. The studies highlighted the manipulation of the available channels resources in improving the network performance.

The basic framework of channel assignment algorithm for MRMC based on the least interfered within the nodes in WMN and fully utilizes the network resources as presented in [5]. The big advantage of MRMC is the nodes can be transmitted or received data simultaneously by exploiting the available channel when assigning a different frequency channel for each radio. Hence MRMC can be reflected as an easy model and the best topology for WMN.

The key contribution of this paper is to discuss and conclude the development of channel assignment algorithm. In this paper, firstly we review the different variants of channel assignment problems (CAP) and secondly, study the

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solution approaches that consistent with aforementioned RMP. Moreover, we address this following research questions:

- RQ1: What problems are trying to be solved in existing channel assignment approaches?
- RQ2: Which solutions are employed in channel assignment approaches?

The remainder of the paper is structured as follows. Section 2 presents a background study of the research area. The methodology that constructs this works is shown in Section 3 while Section 4 presents and classifies the general CAP and the proposed solutions for each identified CAP. Lastly, Section 5 gives a conclusion.

II. BACKGROUND STUDIES

Multiple radios are equipped to MRMC nodes to perform access functionalities and routing and will be used multiple channels where multiple transmissions can happen simultaneously. Compared with SRSC and SRMC, the MRMC maximizes network capacity efficiently, supports flexible connectivity, and decreases the interference among neighboring links [6]. Furthermore, MRMC topology has a great potential to provide the necessary networking infrastructure in WMN to overcome high latency and improve throughput. In MRMC topology, transmission of packets with zero interference when assign neighboring links to different channels because each node has multiple radios.

MRMC involves a channel with a set of orthogonal channels (OC) and partially overlapped channels (POC) and the advantage of MRMC is the flexibility to switch or reassigned the channel of a link if the network topology is changed. The assignment of POC will assist in declining the link congestion and co-channel interference effectively [7]. Even though MRMC technologies bring many benefits to WMN, the use of MRMC topology introduces several issues that need to be considered to optimize the network performance of WMN. The advantages in reduction of interference [8] and improvement of network scalability [12], [13] for channel assignment MRMC WMN has attracted a lot of attention.

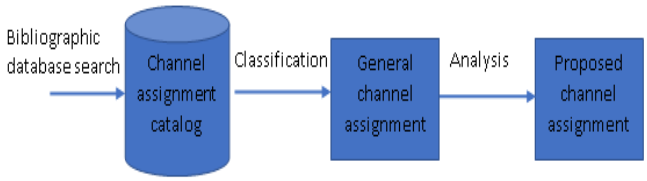

Fig. 2: Research methodology

The mesh clients and mesh routers are connected to the mesh gateways and then to the Internet by wired links. So, there is no issue regarding the network connectivity in channel assignment for cellular networks [2]. However, there is an issue with channel assignment where wired infrastructures are not available or not deemed to be worth deploying. The usage of channel assignment algorithm within the WMN nodes in assigning channels could be more effective in minimizing the impact of interference [1] and optimizing the usage of MRMC capacity [11]. Channel assignment is a main problem that may influence the network performance of MRMC WMN due to design issues. The MRMC nodes equipped with multiple radios that can operate on multiple channels. The problem of channel assignment in providing minimal interference has been proved to be NP-complete [12]. Several research studies have proposed channel assignment algorithms for MRMC WMN as one of problem scopes to improve the network performance.

III. METHODOLOGY & RESULTS

For this work, we implemented the methodology proposed by [6], [7] to address the research questions in Section 1 as illustrated in Fig. 2.

Firstly, we carried out a bibliographic database search including the ACM Digital Library, IEEE Digital Library and Google Scholar using the keyword “channel assignment”. Secondly, to achieve a complete catalog of channel assignment algorithm, the references search for each publication was applied to identify any related works and any publications that did not present channel assignment techniques were removed from the catalog. Thirdly, we classified the recent channel assignment publications according to the general channel assignment problems and lastly, we analyzed the proposed solutions for each problem.

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IV. CLASSIFICATION OF CHANNEL ASSIGNMENT ALGORITHM

Generally, a goal for channel assignment in MRMC is to minimize the interference when two neighboring node utilizes a shared channel. However, one of the main challenges in designing and executing a channel assignment algorithm for MRMC is to assign channels to the radios while minimizing the interference and maximizing the network throughput [15]. In [2] investigated the design issues regarding channel assignment approaches in WMN.

However, the performance of MRMC WMN most affected by the network interference. So, the focus on minimizing the interference by designing the appropriate channel assignment algorithm will significantly optimize the WMN’s performance. The mitigation of interference in WMN will be more effective with the intelligent CA schemes [16]. The consideration of available channels, radios per node and the topology in channel assignment algorithm will assist in minimizing the interference. Channel assignment also influence in making the routing evaluation and routing can change the traffic allocation in WMN. Traffic allocation is a main aspect considered by channel assignment to deduct the interference. According to [7], it proposed an effective

routing algorithm with minimum switching delay and overheads caused by CA procedure. As mentioned above, efficient channel assignment schemes should minimize the interference. So, interference measurement is the important criteria to measure the interference in channel assignment. The benefits of MRMC WMN are noticeable when multiple transmissions can happen simultaneously because of each node equipped with multiple radios, so it can multiply the throughput.

A. Topology Design

Connectivity are extensively used in WMN because to ensure the process of assigning channels to the radios. The main feature of channel assignment algorithm is to sustain the network connectivity where it could efficiently improve the network capacity. According to [17], it proposed a partially overlapped channel assignment algorithm to minimize total network interference while ensure network connectivity.

Table 1: General constraints and proposed techniques for channel assignment

Techniques	Grid	Random	No. of Available Channel	No. of Radios Per Node	Multiple Constraint
MC-POCA [17]	X	X	1~11		
EIZM-CA [8]	X		3	2	
NOCAG [16]	X		3	2	
POCA [18]	X		1~11	2	
ELIA-POCA [14]	X		1~12	2	
CCCA [7]	X		1~12	2~4	X
Distributed Learning-Automata [19]	X	X	2~10		X
CLQ-OLSR [20]	X	X	3	3	X
JPCRA [21]		X	1~6	3	X
JRCAP [22]		X	3~12	2	X
RCART [23]	X		3	3	X
Time-Domain Greedy Heuristic [24]		X	1~12	2	X
CALM [25]	X		3	2	X

MRMC topology has a better layout in grid compared to MRMC random in terms of better coverage area, network capacity, and it is the most suitable scenario for evaluating the performance of channel assignment [8]. In addition, grid is a simplest way in visualizing, implementing and deploying the nodes. Grid layout also better for allocation gateway to achieve maximum throughput [16].

Channel assignment algorithm can be classified as centralized or distributed algorithm. Centralized channel assignment used a single central node to collect all the network information in solving the channel assignment problem as in [18], [14]. However, a distributed channel assignment has no center node and every node runs algorithm to find available channel and switch to the calculated channel. For example, in [19] was proposed a new method for dynamic channel assignment that can be used in physical interference model be implemented in a distributed fashion.

B. Multiple Constraints

In recent years, there has been an increasing amount of literature on constraints in channel assignment for MRMC and constraint can be defined as a relationship or condition among nodes. However, many existed channel assignment algorithm in MRMC could not complies with multiple constraints even though multiple constraints are needed to design an efficient channel assignment algorithm in WMN. This section will discuss numerous developments of channel assignment algorithms that can fulfill many constraints at one time.

Some researchers identified that by jointly channel assignment with another constraints could enhance the process of assigning the channels especially in the routing algorithm. For instances, in [20] considered QOS routing protocol with channel assignment for real-time multimedia communication. In [21], it proposed a solution to find out the near-optimal configuration of power, channel and routing for each flow. Moreover, in [22] employed a new routing metric with clustering algorithm for channel assignment approach to solve the same problem. Also, in [23] discovered that a solution for incoming traffic in WMN by jointly channel assignment and routing.

Furthermore, it considers greedy heuristic solution by modeling the heuristic algorithm Time-Domain Greedy heuristic approximation algorithm that eventually could deliver optimal solution [24] and according to [25] choosing a suitable CA for a given WMN extremely tedious and time-consuming. To avoid that situation, it presented a heuristic solution by introducing a new interference estimation and channel assignment performance prediction algorithm called CALM, which is inspired by social theory. Additionally, in [19] exploited a novel interference estimation approach by following a measurement approach that can be used as the network response to the channel assignment strategy and practically suitable in the real world.

V. CONCLUSION

This work discussed the recent channel assignment algorithms in the past three years and as discussed in Section 4, this work answered two research questions accordingly; we classified the recent channel assignment publications according to the general channel assignment constraints and then highlighting the proposed solutions for each problem. Table 1 shows the general channel assignment (CA) constraints and the proposed solutions that we think significant in the channel assignment developments.

Moreover, Table 1 can suggest different types of design that could be used in to resolve any CA. One of the future direction is to propose a channel assignment for MRMC in WMN is that accommodate the process of assigning channel by jointly with another constraints and applied the heuristic approach to minimize the interference.

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