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Performance Analysis of WMN Backhaul as a Suitable Alternate of Wired Backhaul

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Abstract: Due to flexibility of multi radio and multi hop architecture, Wireless Mesh Network (WMN) is supposed to be the suitable alternate of wired backhaul. In such replacement, interference is being considered as a core problem for the significant performance of WMN backhauls. This paper explores the interference problem which increases due to number of radio and number of hops in particular with the limitation of available orthogonal channels such as 2.4Gz band. In this work we present the comparative performance analysis of WMN backhaul with the matrices of throughput, goodput and round trip time to analyze the effect of number of radios, number of hops, number of channels and the type of channels (orthogonal or non-orthogonal). The analysis is done through OPNET 14 simulator. The results shows that the orthogonal arrangement of channels guarantee approximately twice the throughput corresponding to non-orthogonal arrangement up to multiple hopes.

Keywords: Backhaul, Wireless Mesh Networks (WMN), Orthogonal, Non-Orthogonal, Throughput, Round trip time, Channels

1. INTRODUCTION

In a hierarchical structure of telecommunications network, backhaul is composed of the intermediate links between the backbone/core network and local-loop/access nodes. Recent technologies support high data rate broadband applications to access nodes. This leads to the demand for powerful backhaul so as to shift huge amount of data from multiple users to core network. Current wired options for backhaul connectivity such as DSL, T1, or T3 require high installation cost (Kretschmer, *et al.*,, 2013) and face performance degradation due to bottleneck problem. Alternatively wired backhaul offer significant performance in the limitation of interference and hop delay of wireless backhaul.

The main challenge in replacing wired backhaul with wireless technology is to guarantee efficiency, which usually is offered through a wired backhaul (Narlikar, *et al.,* 2006), whereas in the support of that main requirement, the backhaul of next generation must satisfy some other issues as network efficiency, interference elimination, quality of service (QoS), non-line of sight environment, auto-configuration and self-management. Considering all these standards, wireless mesh networks can be a suitable solution. Besides, Wireless Mesh Networks (WMNs) are economical alternate for broadband applications (Akyildiz, *et al.*,2005). A WMN is two-tier architecture as shown in **(Fig. 1)**, first tier consist one hop connectivity from Mesh clients to its supported Mesh router while second tier is multi hop connectivity from mesh routers to mesh gateway.

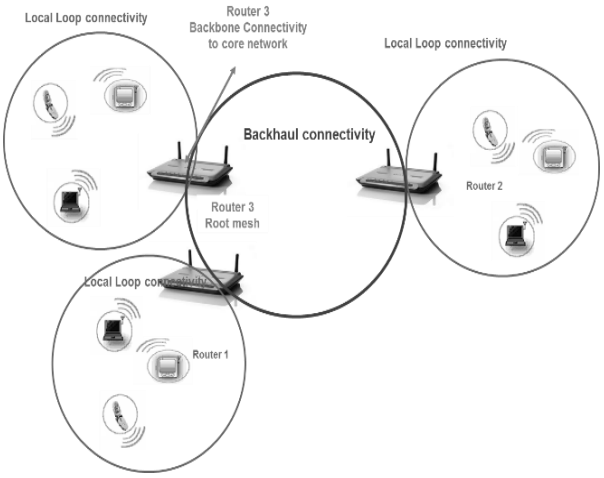


Fig. 1 : Backhaul of Wireless Mesh Network

This work focuses on second tier, where nodes are stationary, connected by directional antennas. WMN support multi radio facility which provide parallel communication and offer more redundant paths to reach to mesh gateway. Such redundancy sustains the chances of network failure in case of traffic overload or link failure (Chung *et al.*,2013). However, the redundant paths in Multi radio concept in not enough to enhance network performance, sometimes it is the main cause for the degradation of performance (which is due to interference of parallel communications on nearby nodes). The required performance demands the channels of every node or interface to be arranged orthogonally. This work focuses on the analysis of WMN backhaul while considering orthogonal arrangement and non-

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orthogonal arrangement of channels in comparison to wired backhaul.

The rest of the paper is organized as the following. Section 22 presents the related work. The experimental work along with simulation design setup and observations are discussed in Section 3. Section 44 reports experimental results and discussion. Finally, main conclusions are drawn in the Section 5.

2. LITERATURE REVIEW

Some studies have focused on evaluating the capacity and throughput of wireless mesh networks with respect to multi hop network. According to the study done by (Cali, *et al.,* 2000) the theoretical level of capacity for centralized network is limited to use single-channel. Following this the authors (Gupta and Kumar, 2000) report that the capacity of the random node of an ad-hoc wireless network decreases as an Asymptotic bound of $1/\sqrt{N}$ in relation to network size n increases, they studied the capacity and throughput of multi-hop networks for two interference models: a protocol interference model and a physical interference model. (De Couto *et al.,* 2003) identified the limitations of spatial reuse of single radio wireless devices as they operate in half-duplex mode, they suggested that the network performance was not particularly dependent on hop count of an end-to-end path, it also varied with link quality. In (Gastpar and Vetterli, 2002), authors proved that throughput could be improved by random selection of single source and single destination, their work considers that every node in network contained a single channel and single radio. Work of (Zhu and Roy, 2005) showed that the node on the part of the total throughput of 802.11 multi hop network with single channel acted like $(1/n\alpha)$, where n represents total network nodes and the exponent α is related to network topology and traffic parameters. According to (Kyasanur and Vaidya, 2005), the frequent switching in multiple orthogonal channels produced more end-to-end delay. Moreover (Kyasanur and Vaidya, 2005) argued that the asymptotic capacity of Multi-channel, Multi-radio networks was more effective. In WMNs, capacity bottlenecks appeared around the gateways, therefore the available capacity for each node is reduced to $O(1/n)$ (Jun and Sichitiu, 2003). The paper (Ramachandran *et al.*,2006) proposed a centralized channel assignment algorithm, where network interference was periodically observed by central server, while the channel assignment was dynamic in nature. The work of (Raniwala and cker Chiueh, 2004) expanded WLAN to a level of backbone of Hyacinth network, where nodes contain several IEEE 802.11a/b interfaces, the system assigns channels in distributed arrangement to connect portable devices. In our previous work, we focused on the interference in WLAN backhaul and proposed a way to minimize interference with orthogonal channel assignment (Abbasi, *et al.,* 2011), and with channel spacing in (Abbasi, *et al.,* 2009). In that contrast, the authors of (Chebrolu, *et al.,* 2006) to (Angelakis *et al.,* 2008) focused on the implementation of directional antennas in WMN. The work of authors (Chebrolu, *et al.,* 2006) targeted to identify the interference concerning directional antennas (antennas placed at 90 degree phase difference). Their work did not present any spatial separation measurement of antennas. Authors in (Ireland *et al.,* 2007) analyzed the network performance of 802.11g, the work was based on quantity study and states that the network performance was dependent on and is related by the placement of directional antennas. Another work on beam forming antennas was presented by (Ramamurthi *et al.*,2008), based on the algorithm of Directionality As Needed (DAN). Their work was to satisfy two purposes: network within minimum cost and offering least interference between the links. Joint work on routing and channel assignment was presented by (Zhou, *et al.,* 2008), they expressed and formulated that the combined optimization of routing and channel assignment as a Mixed Integer Programming (MIP) problem. In the work of (Angelakis *et al.,* 2008), some test-bed measurements were presented based on 802.11a network. The work focused on to calculate the Adjacent Channel Interference (ACI) under the observations of antenna placement, transmission power and system throughput.

3. EXPERIMENTAL WORK

The network shown in **(Fig. 2)**Fig. 2 consists of n nodes and each node has 3 interfaces, one interface working for client hop and remaining two are for connectivity of mesh routers. Double link connectivity for every mesh node provides substitute path as redundancy for WMN backhaul interfaces. Client hops are working on 5 GHz band, while backhaul connectivity is on 2.4 GHz band, which is the focal specification of this work.

3.1 Simulation design

A static topology is designed that utilizes File Transfer protocol (FTP) to transfer files at application level. The physical characteristic is direct sequence and the transmitted power is set to 0.005 watt. The other parameters like Short Retry Limit (SRL) and Long Retry Limit (LRL) are set to 7 and 4 respectively. Whereas beacon Level is set to 0.02 seconds.

For performance analysis of Backhaul, the system is simulated considering three scenarios as following;

1. Network with wired backhaul

non orthogonal channels considering,

a. Single card, single channel
b. Single card, multiple channels
c. Multiple cards, multiple channels

3. Network with WMN backhaul and orthogonal channels with multiple cards, multiple channels

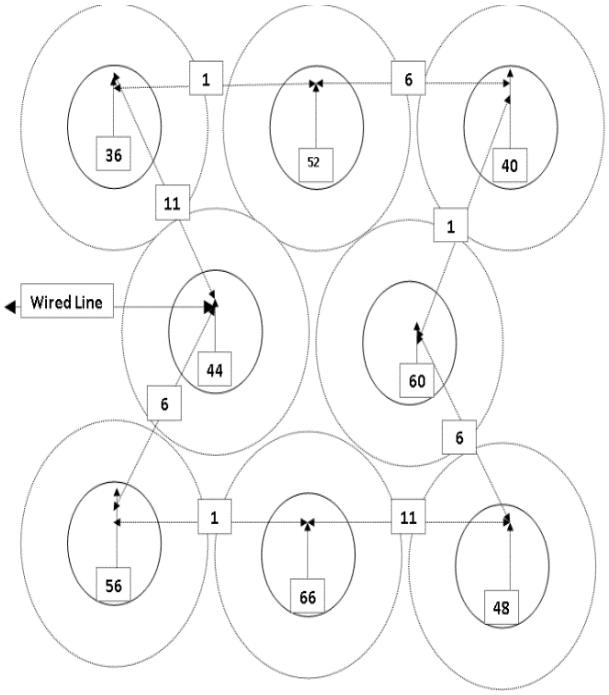


Fig. 2 : The Network Model

3.2 Observations and Analysis

The system is analyzed and observed for the following;

i. **To analyze the effect of hops:** Scenario 1 and 2c is compared in terms of throughput for wired and wireless backhaul.

ii. **To analyze the effect of number of interfaces and channels on delay under the condition when non-orthogonal channels are assigned to nodes:** Scenario 2a, 2b and 2c are analyzed in terms of Round Trip Time (RTT).

iii. **To analyze the performance of system when employing orthogonal and non-orthogonal channels:** Scenario 2c and 3 are analyzed in terms of Delay (Round Trip Time), Throughput, and Jitter.

iv. **To analyze the effect of interference and compare the throughput of wired and WMN with orthogonal and non-orthogonal channel** where the backhaul uses orthogonal and non orthogonal channels.

4. RESULTS AND DISCUSSION

(Fig. 3) shows the comparison of throughput considering scenario 1 and 2c as mentioned in section 3.2(i). The results show that the wired line throughput is constant and is independent of hop count, whereas throughput of wireless network decreases with the increase in hop count. The main reason behind this behavior is generated interface when non-orthogonal channels are used to link connections.

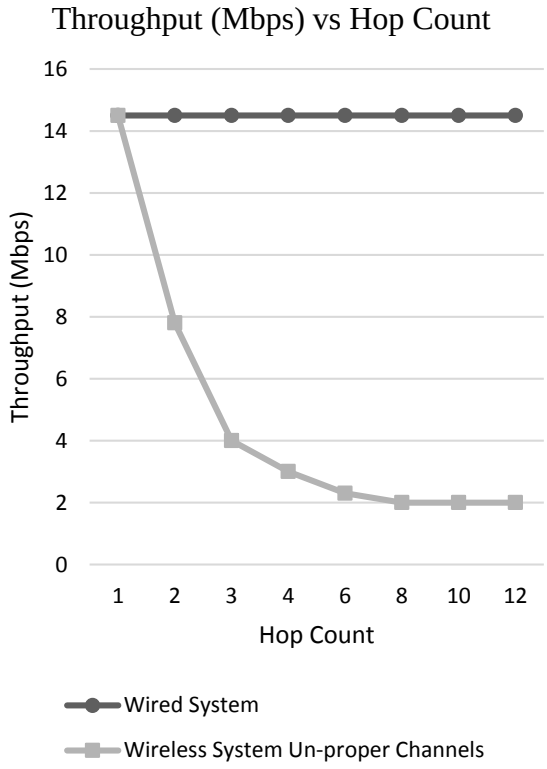


Fig. 3 : Throughput versus Hop Count of Wired and WMN

(Fig. 4) shows the results of task (ii) as mentioned in section 3.2(ii). We observe that there is no major change if single card, single channel or single card, multiple channel assignment is used. The reason being switching delay. In the single card, single channel assignment, the nodes cannot work together with same channel. Whereas in the single card, multiple channel assignment, the nodes work with different channels, but as only one card is in working, so the delay is due to switching delay of channels within single card. Multi-card multi-channel case has minimum delay as there are multiple cards working on different channels.

Beauty of WMN is multi-radio multiple channel support, this feature yields considerable results when the channels are used in proper orthogonal manner. The **(Fig. 5)** shows that, with the equivalent number of cards and channels in orthogonal and non-orthogonal scheme, the RTT of orthogonal case is 60% to 70% smaller than non-orthogonal channel scheme. **(Fig. 6)** instead shows the goodput of orthogonal case, which is approximately double than non-orthogonal channel scheme. **(Fig. 7)** presents the results of Jitter for both the cases. The Jitter Delay behave similar to RTT and its 60% to 70% smaller in the case of orthogonal channel scheme. Results of **(Fig. 5) (Fig. 6)**, and **(Fig. 7)** show that the orthogonal channel scheme enhance the system performance due to proper handling of channels to sustain interference.

(Fig. 8) shows the results of throughput considering orthogonal and non-orthogonal schemes as compared to wire-line throughput. We observe that with proper orthogonal channel assignment, we can get considerable throughput.

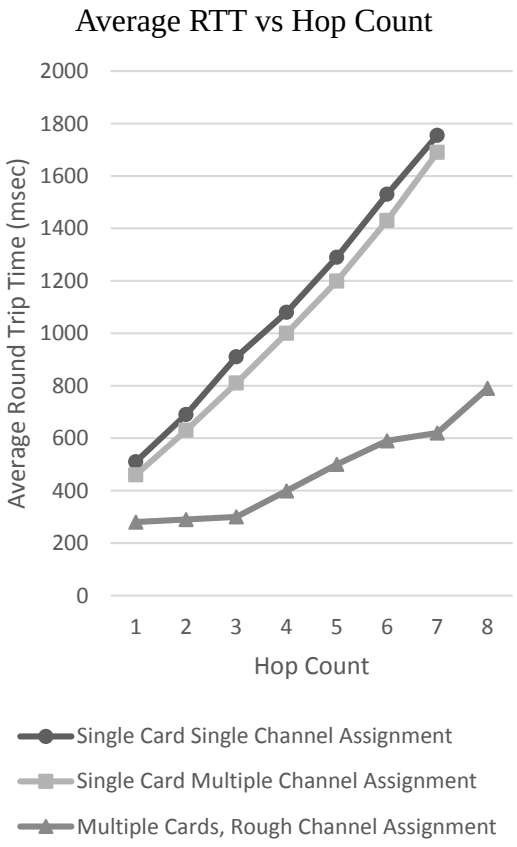


Fig. 4: Avg. RTT vs Hop Count of WMN with non-orthogonal channels

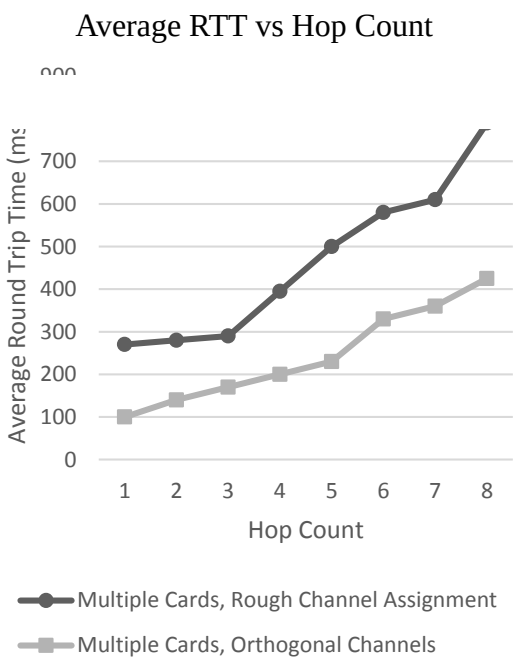


Fig. 4 : Avg. RTT vs Hop Count of WMN with orthogonal and non-orthogonal channels

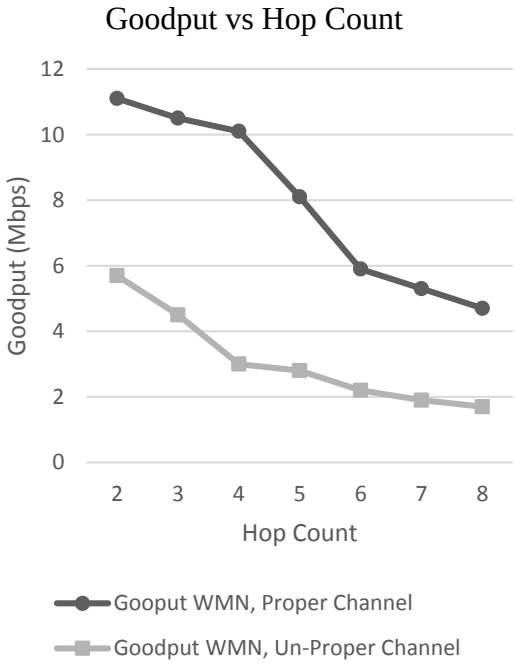


Fig. 5 : Goodput vs Hop Count of WMN with orthogonal and non-orthogonal channels

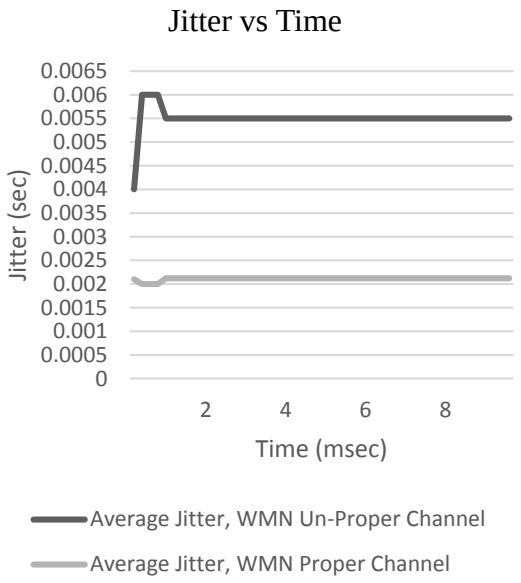


Fig. 6 : Jitter vs Time of WMN with orthogonal and non-orthogonal channels

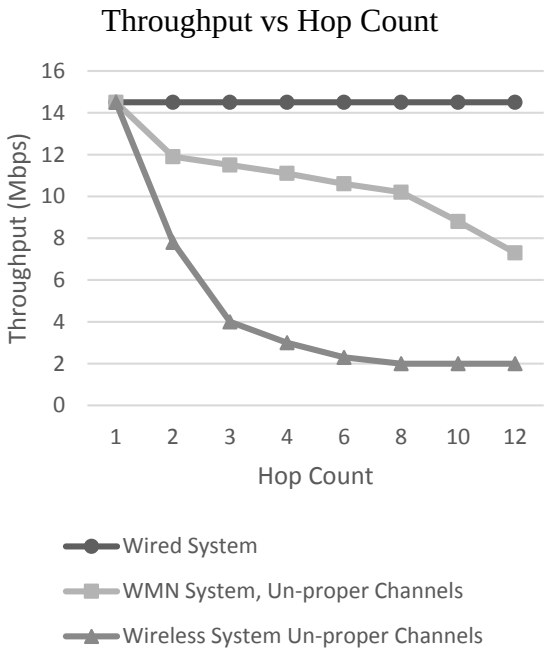


Fig. 7 : Throughput vs Hop count of WMN with orthogonal and non-orthogonal channels

5. CONCLUSION

In this work, we have used various task to analyze the performance of WMN as a suitable alternate of wire-line backhaul. The results show that the system performance increases with the number of cards (radio) and number of channels. Furthermore, the performance of WMN backhaul is shown to improve averagely more than 50% in terms of throughput and delay. Thus suggesting a suitable alternate for wire-line backhaul.

However, the efficiency of wireless Mesh Networks (WMN) in the multi-radio multi-channel environment is dependent on allocation and management of channels in proper order, so as to minimize interference sources. Note that the improper channel assignment generates more interference and this will increase with number of hops.

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