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Channel Spacing for ACI control on 5 GHz WMN Backhaul

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Abstract: In this paper, we formulate a channel assignment scheme for wireless mesh backhaul. The work deals to enumerate the effect of Adjacent Channel Interference (ACI) with proper channel space. The work considers interflow and interaflow links in the support of directional antennas for 802.11a backhaul. Interference nodes are identified by neighbouring directed graph and channel assignment problem is solved by using greedy algorithms. We evaluate work by simulations through OPNET modular 14. Framework of work could act as an imperative way to enhance the network performance. In contrast, the results shows that the proposed scheme offer meaningful throughput gains and significant decrease in delay with the selection of channel space to nodes. Obtained results shown that network performance raise and approximately twice as compared to system with adjacent nodes on consecutive order of channels.

Keywords: Backhaul, ACI, 5GHz, Channel spacing, WMN, Interference.

1. INTRODUCTION

Support of Multi radio in wireless networks enhance the capability of network by running multiple concurrent sessions on different radios, this may lead channel interference in system if channels are not properly configured. Broadly channel interference is categorized as Co-Channel Interference (CCI) and Adjacent Channel Interference(ACI) (Qiu, *et al.* 2007). The interference level depends on two parameters in network; number of channels and the nature of channel (orthogonal and partially overlapped). It is been observed in this work that channel orthogonality is not sufficient to avoid interference, with channel orthogonality a proper channel spacing is essential to avoid channel leakage. This leakage effect is known as ACI where the channel spacing is supposed as guard band between channels. Interference, specifically ACI, damages multiple sessions which are running on nearby channels, hence ACI should be managed carefully (Cheng, *et al.* 2006). The work is in support to analyze the effects of channel spacing towards ACI in MR-MC-WMN backhaul which is extension of (Abbasi, et al 2009), where the idea was implemented in WLAN networks.

The work uses a combination of physical spatial and channel spatial to control and reduce ACI. At physical level it is controlled by directional antenna and channel spatial is managed by proper channel spacing by channel assignment. ACI effect is evaluated under protocol model with interflow (direct) and intraflow (directional) backhaul links for 802.11a, 5 GHz band.

The 5 GHz ISM band is 300 MHz wide band, it contains total 12 channels. **(Fig. 1)** shows this arrangement. Channel bandwidth is 20 MHz (Adya *et al*,. Oct 2004). The 5 GHz band named as "Unlicensed National Information Infrastructure (U-NII)" band in Amrica and consists of three sub-bands: UNII1 (5.15-5.25 GHz), UNII2 (5.25-5.35 GHz) and UNII3 (5.725-5.825 GHz). Each sub-band having 4 channels (Kapp, 2002).

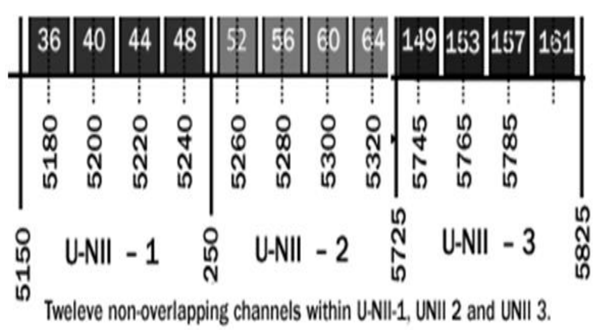

Fig. 1 UNII bands of 5GHz (Kapp, 2002)

Road map of paper is as follows. Literature review is summarized in Section II. In Section III, system design is discussed. Greedy algorithm for channel assignment is presented in section IV. Section V contains description about simulation setup and parameters. Section VI contain results and discussion followed by conclusion and references.

2. LITERATURE REVIEW

In the literature review we found that dealing with ACI by different techniques leads considerable enhancement in network efficiency. In (Lim, *et al.* 2016) worked on channel assignment scheme to support

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multiple broadcasts. The scheme controls an overlapped frequency range covered by adjacent channels through advertising of used channel by sender. This is done through a broadcast signal named "Signalling via Overlapped Band (SOB)". A windowing technique for "orthogonal frequency-division multiplexing (OFDM)" network is introduced in (Guvenkaya, *et al.* 2015). This provides the minimum "Adjacent Channel Interference (ACI)" and best possible time-frequency control. Work of (Zubow, *et al.* 2012) focuses "Adjacent Channel Interference (ACI)" in 802.11n network. The work highlights that in multi radio systems where radios are placed on closely channels creates maximum interference among concurrent communication sessions by ACI and interference from hidden nodes. The suggested solution was based on control of transmitting power to reduce ACI in systems. Work of (Cheng, *et al.* 2006) evaluates the effect of ACI for parallel transmissions on frequency-division multiplexing (FDM), ad-hoc and time-division multiplexing (TDM) techniques. Findings suggest that TDM work efficiently in support of ACI reduction. Angelakis focused ACI in (Angelakis, *et al.* Jan 2008) (Angelakis, *et al.* 2007). The study uses "Signal to Interference and Noise Ratio (SINR)" to compute the interference due to adjacent partially overlapped channels in 802.11a standard. The work emphasis on spectral properties for channel separation, such as spectral mask, channel bandwidth and guard band. Authors of (Zhang, *et al.* 2012) identified that directional antennas with minimum distances enhances the ACI level in 802.11a/g networks. The used metric for evaluation was 'Signal to Interference and Noise ratio (SINR)".

3. SYSTEM DESIGN:

Study focus on infrastructure based WMN backhaul. Static nodes of backhaul are linked with directional antennas, where every node supports two backhaul interfaces and one interface is reserved for user communication. Work contributing to identify the interference links by neighbouring directed graph for 2nd hop of directional nodes and single hop of direct links. Directional nodes are identified as "u" and "u+1" while direct node identified as "v", their connecting links recognized as e1, e2 and e3, as shown in figure 2.
The Graph is identified as G(U, V, E), where the interference nodes are In = (u, u+1, v).

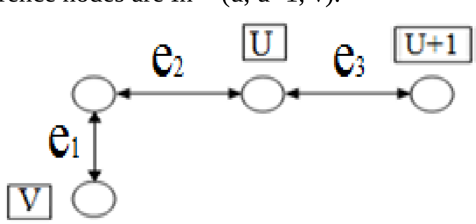

Fig. 2 Interference nodes by neighbouring directed graph

Work emphasis to assign channels to these identified links with atleast one channel space. This reduces the effect of ACI.

4. GREEDY CHANNEL ASSIGNMENT ALGORITHM

This section presents the pseudocode of greedy algorithm for channel assignment of 5 GHz backhaul links. The work selects three channels from input channels with minimum space of one channel. These channels assigned links which are in interference direct and directional links. The process repeats to assign channels for every node and link. This leads to reduce adjacent channel interference in the system.

Input: Graph G=(U,V,E);
Available channels (36, 40, 44, 48, 52, 56, 60, 64, 149, 153, 157, 161)
1. Find conflict links E_c for each node v belongs to G(U, V, E)
2. For each interference area In = u, u+1, v, select three channels with minimum one channel space
3. Assign 1st channel = u,
4. Assign 2nd = u+1,
5. Assign 3rd channel = V,
6. Where Ec ≠ EC of (1) & selected channels are alteast with one channel space, Repeat from 1 to 6 for every node belongs to G,
7 end.

5. SIMULATION SETUP AND PARAMETERS

For the 5GHz band design there are two scenarios have been proposed based on Backhaul nodes. These scenarios are without channel space and with channel space. These proposed scenarios contain 24 collective nodes and a FTP server is dedicated for the service. A static topology is proposed containing a sum of eight access points; of which every candidate access point containing three interfaces for the service of three users at an average

These designed access points comprise of three ports each. The two ports have been used for backhaul connectivity whereas the one port is use for functionality of access point. The system is smooth up to 80ms but after this timeframe, the FTP clients traffic is distributed uniformly distributed client traffic can be seen generating.

(a) System model without channel spacing (Backhaul nodes)

The first scenario is without the space among the channels. These channels spaces design which is assigned to backhaul links result in Adjacent Channel interference specifically in the direct and directed links. **(Fig. 3)** illustrates the static channel assignment at backhauls. The first access point names as AP_0 is in direct connection to second access point namely AP_1 which is on the channel number 36. This connection continues to the access point AP_2 containing channel 40. It is obvious that channel 36 is adjacent to channel 40 having no guard band resulting in adjacent channel interference in the designed system.

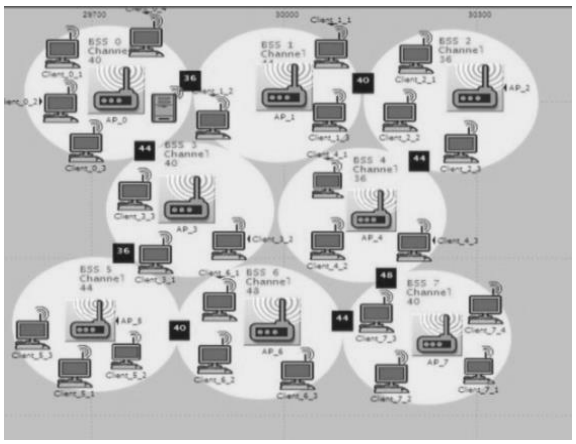

Fig. 3 Backhaul links without channel space

(b) System model with channel spacing (Backhaul nodes)

The other scenario, the backhaul links contain one or more channel space amongst the assigned channels. In this design the guard band is created and reduces the adjacent channel interference in the designed system. (Fig. 4) illustrates the backhaul assignment as static channels with space

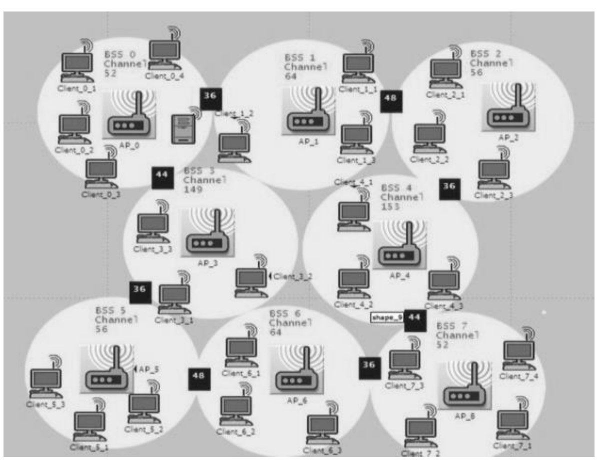

Fig. 4 Backhaul links with channel space

The first access point named with AP_0 links with two other access points adjacently. The Access point named AP_1 assigned channel number 36 whereas the access point named AP_3 is connected with 44 channel number. The directional link AP_2 assigned 48 channel. These all selected channels are spaced by gape of one channel. The system is seen producing high performance when channels spacing are at the proposed level.

6. RESULTS AND DISCUSSIONS

To evaluate the effect of adjacent channel interference, results of two scenarios are presented: channel Spacing 5GHz and No-channel spacing 5GHz. The desired results are simulated by OPNET 14 Modular. The work quantified the effect of ACI in terms throughput and delay. The throughput in bits per second is expressed by three formats: Figure 5 plots Time line Throughput, Figure 6 shows average throughput and Figure 7 presents FTP throughput.

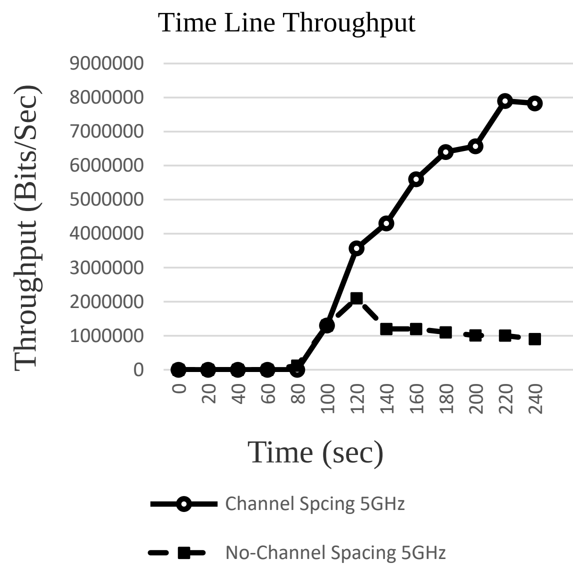

Fig. 5 Timeline Throughput

Results of Figure 5 develop an understanding about the variation in throughput; it shows that with proper channel spacing there is remarkable increase in throughput in comparison to no channel spacing. Initially throughput is zero because system is in idle conduction up to 80 sec as clients from BSS_0 starts transferring files from ftp server by using uniform distribution, the throughput starts to increase. Up to initial 40 seconds From 80 sec to 120, an increase in throughput was observed for both scenarios, it is because of less dense environment. After 120 seconds, as System starts dealing with events from various BSSs then a major difference in Throughput have been observed. Channel spacing average graph almost increases linearly up to 0.8 Mbps, while time line throughput of no channel spacing decreases with increase in time and events and reach to peak level of was 0.2 Mbps.

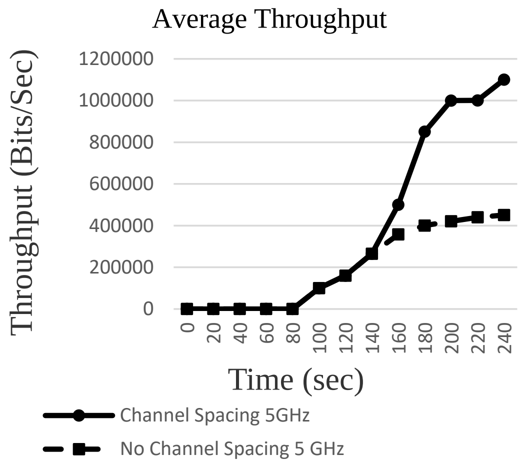

Fig. 6 Average Throughputs

In the case of Average throughput **(Fig. 6)** shows that system is idle up to 80 seconds. Up to 140 seconds both scenarios have same variation of throughput. After 140 seconds with involvement of events channel spacing scenario boots the throughput and reach up to 1.1Mbps while no-channel spacing scenario reach up to peak value of 0.45 Mbps.

Fig, 7 shows the throughput at application layer as the response of FTP. This follows the same variation as average throughput; system is idle up to 80 seconds. Up to 140 seconds flowing same variation. There after channel spacing throughput reach to 0.62 Mbps while no channel spacing touch to 4 Mbps.

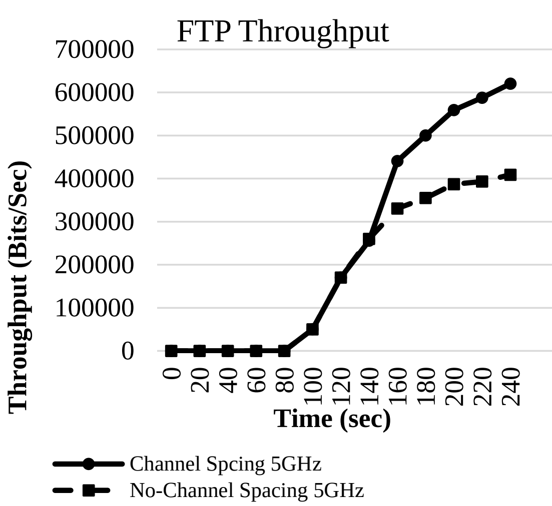

Fig. 7 FTP Average Throughputs

Delay analysis graph is presented in figure 8, although up to initial 80 seconds the events were not occurred but systems observed some delay, this is known as background delay. There after an increase in delay noticed with the increase of time for both scenarios. In channel spacing scenario, the delay's peek value reaches up to 4.2msand for o-channel spacing it has 5.4ms.

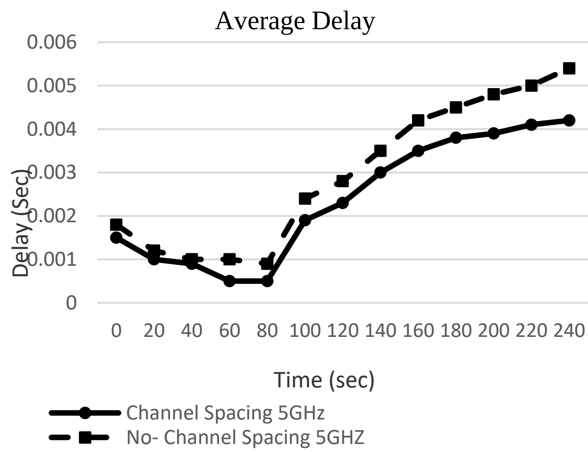

Fig.: 8 Average Delay

Justification; Channel spacing 5GHz System:

For further justification the system is simulated with variation of user density which explores clear authentic approach in support of proposed work. In figure 9, Average delay linearly increases with increase in user density. It is clear from results that throughout the channel spacing scenario have minimum delay. At start it is observed that the variation difference in both scenarios was not much high but as user density increases the difference gets high and it supports that with proper channel spacing in 5G the delay could be minimized in more dense environments.

Similarly for throughput case as the user density increasing the throughput increases with channel spacing. **(Fig. 10)** depicts average throughput vs number of users for both scenarios

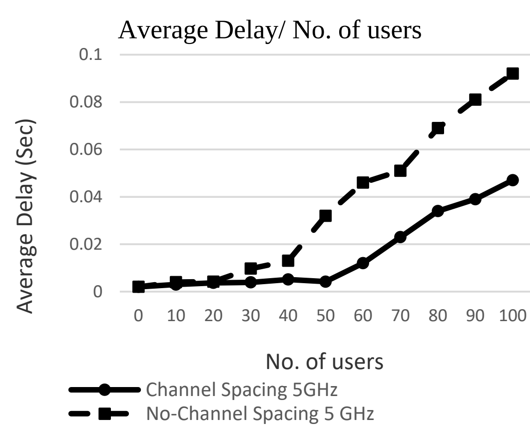

Fig. 9 Average delay vs No. of user

As seen in figure 9 that delay was minimum when the number of users was minimum at initial stage here in Fig. 10 simulated results shown maximum throughput achieved at first few points and in last when number of users become dense then over all systems throughput was relatively low, the reason is more ACI generated due to more users with no-spaced channels.

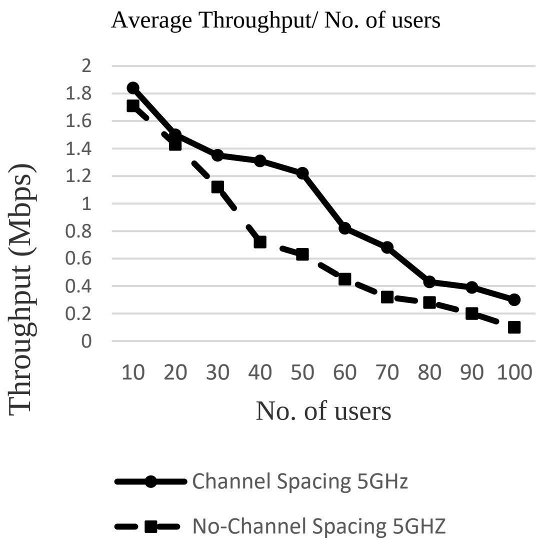

Fig. 10 Average throughput via No. of users

From results we found that the although 5GHz band contains 12 orthogonal channels but without proper channel spacing the system performance would be degraded due to ACI, to increase systems performance proper channel spacing is needed with channel orthogonality. The channel space provides some guard space between channels which minimize the possibilities of adjacent channel interference

7. CONCLUSION

It is observed that with the proper attention on channel spacing, the network achieved higher throughputs. The proposed channel assignment is applied in 802.11a standard working on 5 GHz, supporting 12 orthogonal channels. Selection of 5 GHz band verified the condition that dealing ACI needs proper channel spacing even multiple orthogonal channels are available. Results show that performance of system could be doubled with proper channel spacing. The concept produced considerable results in dense networks.

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