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Jayaraman, R, Raja, G, Bashir, AK, Hussain, CS, Hassan, A and Alqarni, MA (2018) Interference Mitigation Based on Radio Aware Channel Assignment for Wireless Mesh Networks. *Wireless Personal Communications*, 101. pp. 1539-1557. ISSN 0929-6212

DOI: <https://doi.org/10.1007/s11277-018-5776-4>

Publisher: Springer Verlag

Version: Accepted Version

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Interference Mitigation Based on Radio Aware Channel Assignment for Wireless Mesh Networks

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Abstract

An intricate network deployment for high demand users leads to simultaneous transmission in wireless mesh networks. Multiple radios are adapted to individual nodes for improving network performance and Quality of Service (QoS). However, whenever multiple radios are assigned to the same channel, co-located radio interference occurs, which poses a major drawback. This paper proposes a Radio aware Channel Assignment (Ra-CA) mechanism based on a direct graphical model for mitigation of interference in multi-radio multi-channel networks. Initially, the co-located radio interference is identified by classifying non-interfering links for simultaneous transmission in the network. Proposed channel assignment mechanism helps in allocating the minimal number of channels to the network that mitigate co-located radio interference. Performance analysis of the proposed Ra-CA strategy is carried out compared with other existing techniques, like BFS-CA and MaIS-CA, in multi-radio networks. Simulation results demonstrate that the proposed channel assignment scheme is more efficient compared to the existing ones, in terms of QoS parameters like, packet drop rate, packet delivery ratio, transmission delay and throughput.

Keywords: Multiple-radio, Channel Assignment, Co-located Radio Interference, Mesh Networks and QoS

1. Introduction

Wireless Mesh Networks (WMNs) [1] support multiple hop connectivity with self-organized, self-configured nodes, which can also act as routers to extend network coverage area. WMN [2] [3] plays a promising role to provide continuous connectivity to the users in a wireless network environment. Recent wireless networking technologies strive to connect more users using surplus network resources and to provide seamless communication. Next generation networks such as Long Term Evolution – Advanced (LTE-A) [4], with channel allocation range from 2-3 GHz band, employs Orthogonal Frequency Division Multiplexing (OFDM) to improve network data service

provisioning. OFDM supports assignment of multiple, closely-spaced, orthogonal sub-carrier radios to an individual node. This capability improves bandwidth provisioning to individual users by enabling simultaneous transmission of data streams, but at the same time suffers from the problem of co-located interference.

The two main categories of interference, namely external and internal interferences, are elaborated in [5] [6]. External wireless devices, such as Bluetooth, which communicate over the same frequency, lead to external interference of uncontrolled activities in the network [7]. During various processes within the network, such as network deployment, resource allocation, routing and scheduling schemes, the communications between neighboring nodes over same frequency could lead to internal interference [8]. Usually multiple radios are placed in a single node for simultaneous transmissions and to provide reliable data services in the network. When multiple radios use same channel or timeslot for data transmission, co-located radio interference could occur. In case of WMNs, where frequent interferences could originate between neighboring nodes, an efficient channel allocation scheme offers a significant impact on the performance of the network. The underlying interference problems also lead to network disruption during establishment of multiple connections and degrade QoS. Various Channel Assignment (CA) schemes [9] [10] have contributed for identifying and mitigating the interferences in WMN. The conflict graph concept is commonly employed to address interference issues in WMN. For Multi-Radio Multi-Channel (MRMC) networks, the conflict graph concept can be extended as MRMC conflict graph [11] [12]. The conflict graph approach to multi-radio generation using improvised vertex coloring algorithm is modeled in [11]. The works proposed in [24] [33] [34] discuss the problems of interference related to multi-radio multi-channel networks. However, to the best of our knowledge, existing CA schemes cannot achieve optimal network state based on the number of channels required for the MRMC network.

The focus of this work is to propose Radio aware Channel Assignment (Ra-CA) strategy, which can minimize required number of channels in case of a complex multi-radio network. This study assumes a centralized environment where Base Station (BS) acts as a central entity and maintains all the activities of the Subscriber Stations (SSs). Hereafter, SS is referred to as mobile equipment or device and BS acts as a mobile tower, which monitors and controls activities of one or more SS's.

The proposed scheme attempts to mitigate co-located radio interference problems related to MRMC networks by adopting different channels using CA strategy. The Ra-CA strategy incorporates an independent set algorithm and a two-folded graphical algorithm, which guides it to determine interference links and to assign minimum number of channels required in the network. Subsequently, the requirement of minimal channels in a multi-hop network help to reduce network control traffic and transmission delay.

The main contributions of this work are as follows:

- i. This study employs network topology to classify interfering and non-interfering links.
- ii. A channel assignment strategy, hereby referred as Ra-CA, is proposed that helps to mitigate interference and to calculate a minimal number of channels required for an improved QoS provisioning in the network.

The rest of the paper is organized as follows: The discussion on related work is given in section 2. In section 3, the problem of co-located radio interference is defined for WMN. Section 4 details the proposed Ra-CA strategy using direct graphical method with minimal channel utilization. The proposed Ra-CA strategy is analyzed and evaluated in Section 5. Section 6 of this paper states the conclusion.

2. Related Work

Future networking technologies promise to offer high-speed wireless networks with seamless connectivity. However, they also face technically challenging problems like interference [13]. Interference plays a major role in degrading network performance metrics like throughput, scalability and latency in the network. Several types of interferences [35-37] could occur during dense node deployment and synchronization. Channel assignment, routing and scheduling techniques play a vital role to mitigate interference problems in wireless networks [9] [10]. To address the problem of interference, interference aware approach is proposed in [14], which helps to reduce interference by assigning the blocking metric, i.e., number of interfering nodes at the intermediate and improving throughput in WMN [14].

Generally, when a transceiver radio of any node tries to perform more than one transmission and reception in a single time slot, primary interference occurs. When a receiver is located within communication range of more than one sending transceiver during the same time slot, secondary interference occurs. Interference can also be categorized into primary and secondary interferences as explained in [15]. To address the problem of primary and secondary interferences, modified channel assignment (CA) strategies [16] [38] can effectively be deployed. For WMN networks, Clique Partitioning (CP) technique based on channel assignment is proposed to mitigate the interference problems in MRMC networks [15]. The interference graph is formed by classifying different links to provide a minimal number of channels. Channel assignment, scheduling and routing problems are NP-complete and considered challenging issues for MRMC networks.

Overhearing is a phenomenon that occurs when sensor nodes can hear each other's communication and thus subsequently cause interference. In order to resolve overhearing (also known as listening) interference problem, joint CA and routing approach in the multi-hop network is proposed in [16]. Routing is replaced with network coding as it allows nodes to randomly mix packets during overhearing, prior to forwarding them. A time partitioning approach, specific to address primary interference, is proposed in [17] that help to manage network traffic demands and radio channel constraints. Efficient channel allocation can help to minimize traffic congestion in WMN. The CA schemes proposed in [18], [19] and [20] report to mitigate co-channel interference i.e., the same frequency between two nodes that are adjacent in multi-radio multi-channel networks. CA schemes based on conflict graphs are reported to contribute significantly towards improved channel utilization and thus reduce interference problem. The interference aware channel assignment algorithm proposed in [21], for multi-radio WMN, helps to assign channels to the radio that minimizes co-located interference.

In [22], an interference estimation and CA performance prediction technique is proposed for MRMC- WMN deployments, using conflict free graph approach [22]. CA scheme used for

performance estimation is based on computational cost and algorithmic complexity. However, in this work, throughput based on individual link quality estimation is not considered.

A generic algorithm is proposed in [23] for conflict graph generation, which is used to identify and estimate interference in wireless networks. However, no algorithm is formulated based on channel assignment strategy for co-located radio interference problem. Where as the existing Breadth First Search Channel Assignment (BFS-CA) [11] and Maximal Independent Set Channel Assignment (MaIS-CA) [24] algorithm are compared for performance analysis [23].

Future wireless networking technologies, such as LTE-A and 5G, strive to improve provisioning of data services by considering QoS issues related to transmission delay, jitter, bandwidth, etc. [25] [26]. Multi-radio can be enabled in each node for simultaneous transmission and to improve network performance. However, in case of complex networks with dense deployment, this may also result in severe interference problems. Channel assignment, routing and scheduling [27] play a role in mitigating the interference (i.e. NP-Complete problem) to achieve minimal channel utilization.

The existing CA algorithms presented in [11] and [24] establish that optimal channel assignment which addressing radio based interference problem is NP-complete and therefore network optimality cannot be achieved. The broadband wireless networks often use OFDM to provide better QoS in WMN. Such wireless networks using OFDM have to enable multi-radios, to support simultaneous transmissions, in each network node. This can lead to occurrence of interference and thus deterioration in network performance. CA based strategies can help to mitigate interference related to multi-radios in WMN. The main objective of any CA strategy is to provide QoS with minimal number of channel utilization. In this study, we address the problem of multi-radios that are co-located and co-channel interference and minimal number of channels required for such network is determined to achieve improved Quality of Service (QoS) in WMN.

3. Problem Definition

For any MRMC network, such as the one represented in Fig. 1(a), the topology of the network can be represented as a Graph $G(V, E)$, where V denotes a set of vertices and E denotes the set of links between network nodes. Co-channel interference occurs when neighbouring or adjacent nodes use same channel. Let's assume that the nodes are enabled with radios ' r_n ' where $n \in 1$ to N . Then, $G(V, E)$ can be represented as, $G(V(i)r_n, E(i))$, where ' r ' denotes radio and ' n ' is the number of radios enabled for any node.

$$\text{Where, } V(i)r_n = \{(V(1)r_1, V(1)r_2, \dots), (V(2)r_1, V(2)r_2, V(2)r_3, \dots) \dots (V(n)r_1, V(n)r_2, \dots)\} \\ E_i = \{E_1, E_2, \dots E_n\}. \text{ 'i' \& 'n' } \in 1 \text{ to infinity.}$$

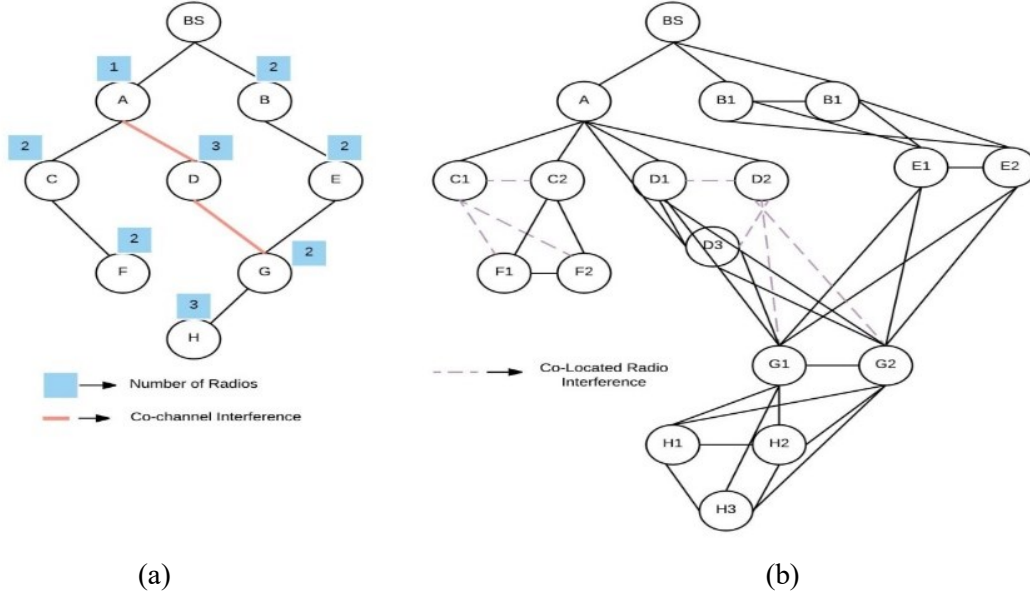


Fig. 1 a) Network topology b) Network topology with radios represented as nodes

A network node that is enabled with multiple radios, is represented here such that all its radios are linked with those of neighboring nodes, forming a fully connected graph. The linear MRMC network flows, equipped with multiple radios are represented in Fig. 1(a) and 1(b). This study assumes that nodes in $G(V(i)r_n, E(i))$ are densely connected and co-located radio interference occurs between adjacent radios within a node. First, interference identification helps to classify conflicting links in the network by identifying interference. As far as QoS is concerned, assigning different channels does not contribute towards improvement in network performance. A two folded algorithm converts the unlying graph into a Line graph 'L' as depicted in figure 2. This is carried out to distinguish and classify conflicting and non-conflicting links, in order to avoid occurrence of interference problem.

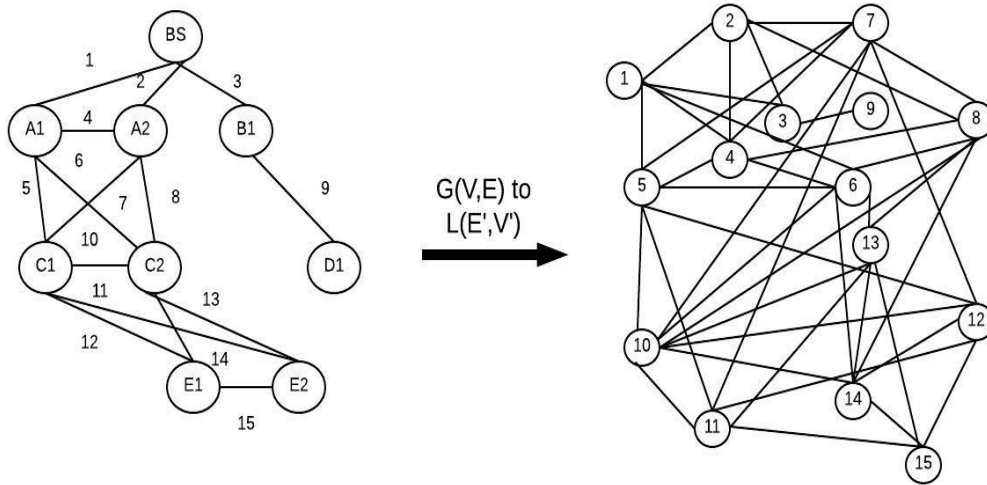


Fig. 2 Network into Line Graph L (G)

The proposed algorithm then convert Line graph 'L' into a Path graph 'P' to obtain minimal number of channel utilized in the network by mitigating co-located radio interference. Sample path graph sequence of Two-Folded CA algorithm is presented in Fig. 3.

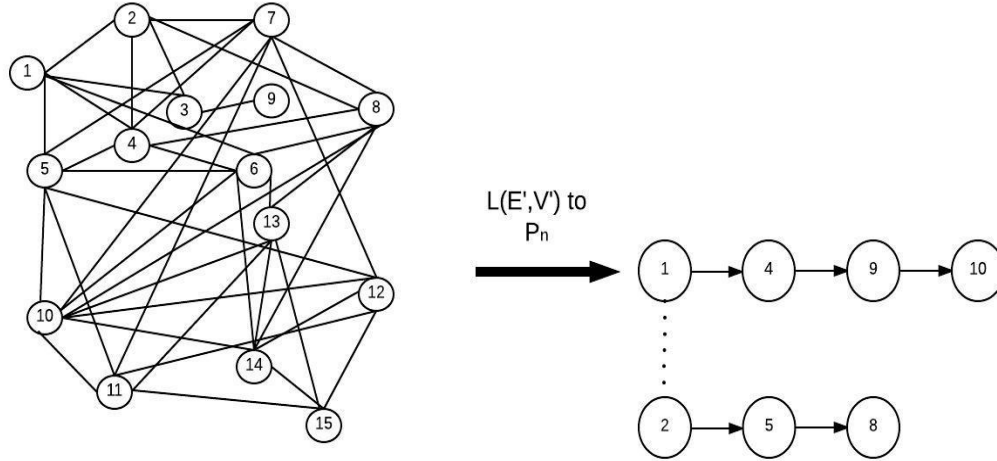


Fig. 3 Line Graph $L(G)$ into Path Graph P_n representation

4. Proposed Ra-CA strategy

In this section, we proposed Ra-CA strategy that solves the problem of co-channel and co-located radio interference to determine minimal number of channels required in MRMC network for effective QoS. The Ra-CA scheme is subdivided into two algorithms; independent set and two-folded algorithms, which are developed based on direct graphical method and the classification of interfering and non-interfering nodes. The independent set algorithm forms a non-conflict index, which are interference free links with different channel utilization. Two-folded algorithm helps to reduces network traffic and transmission delay, which resolves the co-located radio interference in MRMC networks.

4.1 Interference node level (m_i):

Interference node level (m_i) [27, 10] is defined here as the number of connected conflicting nodes to get interfering links and is represented in equation (1).

$$m_i = \sum_{k=1}^n I_k \quad \text{---- (1)}$$

Where, k is the connected neighbor nodes of a particular node 'I'. Degree sum (D_s) is calculated for each transmission from source to destination as:

$$D_s = \sum_{j=0}^k (\sum_{i=0}^n m_i) \quad \text{---- (2)}$$

Where, i is the connected neighbouring nodes from 1 to n ; j is the transmitting node from source to destination from 1 to k .

The interference node levels help to schedule link transmission events to be processed, as nodes are enabled with multiple radios. The interference graph for the particular network is then generated to classify neighbouring and non-neighbouring links.

4.2 Independent set algorithm:

Independent set algorithm helps to classify interfering and non-interfering links by identify the co-located radio interference in the network. With the line graph 'L', minimal interfering node D_s is selected. Then each vertex in E_n , which is non-neighbouring set of D_s , is chosen and minimum degree vertex is sorted out from the list E_n . Again the minimum interfering node D_s is selected so that the non-adjacent vertices in E_n are listed. This procedure is repeated till all D_s elements in the network are processed.

The selected vertex of D_s forms a non-conflict index that is feasible and interference free. All the vertices of 'L' are selected and several index sets are formed. These non-conflict index sets help to avoid both co-located radio and co-channel interference with free assignment of a channel to the links in the network. Considering $v \in L(G)$ and $d(E_1)$ and $d(E_2)$ are the two vertices having same minimum degree, then choose any one $[d(E_1) || d(E_2)]$ such that it may not create any impact.

Algorithm 1: Independent set $S(v)$

Input: Line Graph $L(G) = \{E', V'\}$

Output: Degree $d(E_n)$ and Minimum Degree $\delta(L(G))$.

1. Find the independent set $S(v)$ based on the Line Graph $L(G)$.
 $S(D_s)$ as $\{E_1', E_2', \dots, E_n'\}$, Where D_s is the Degree sum.
2. Find the degree of each vertex in $L(G)$ as,
$$d(E_n) = \sum_{(a_i, a_j) \in E} (a_i, a_j) \text{ where } E_i \text{ adjacent to } E_j$$
$$i \text{ and } j = 1 \dots N$$
$$n = 1, 2, \dots, \infty$$

With the Degree of each vertex with the non-neighboring set of D_s ,
3. Find the minimum degree (δ) vertex v in N_T .
$$\delta(L(G)) = \wedge \{d(a_n) | E_i \in v\}$$

4.3 Two folded CA algorithm:

In two folded algorithm, one fold decides non-conflict index sets and in the other one non-conflict index sets are represented as Path graph ' P_n '. For each ' P_n ', the independent set $S(v)$ algorithm is repeated for CA index sets, which provide a minimal channel utilization to the particular network.

The graphical conversion of the topological graph 'G' to 'L' and then subsequently to ' P_n ', helps to mitigate co-located radio and co-channel interference problem in WMN. Path graph ' P_n ' index sets provide minimal number of channels needed for WMN to provide better QoS.

Algorithm 2: Two-Folded CA Algorithm:**Input:** Independent Set $S(v)$ **Output:** Index with number of channels

1. With the Independent Set $S(v)$, find the degree $d(E_n)$ and Minimum Degree $\delta(L(G))$ till it gets NULL.
2. Then sequence based on selected $d(E_n)$ and $\delta(L(G))$ is computed and denoted as non-conflict Index $I_V = \{I_{V1}, I_{V2}, \dots, I_{Vn}\}$ where $n = 1, 2 \dots \infty$; $I_{Vn} = \{e_1, e_2, \dots, e_n\}$.
3. With each I_V , a Path graph P_n is computed where $n = 1, 2 \dots N$.
4. Repeat Step 1 to get sequence based on selected $d(E_n)$ and $\delta(L(G))$ denoted as CA Index $I_C = \{I_{C1}, I_{C2}, \dots, I_{Cn}\}$ where $n = 1, 2 \dots \infty$; $I_{Cn} = \{e_1, e_2, \dots, e_n\}$

5. Performance Analysis

The following network configurations, presented in table 1, are assumed for performance analysis of the proposed Ra-CA scheme.

Table. 1 Network Configuration

Parameter	Value
Modulation Type	OFDM_QPSK_1_2
Transmission Coverage	500 m
Network Interface Type	WirelessPhy/OFDMA
Antenna	Omni Antenna
Routing	DSDV
Interface Queue Type	PriQueue
Schedule Type	Wimax Scheduler
Scheduling Flow	rtPS_SCHEDULING BE_SCHEDULING
Packet Size	1000 bits
Agent	PT_WIMAXBS
Seed RNG	HEURISTIC_SEED_SOURCE
UIBurst	UIUC_FAST_RANGING
DIBurst	DIUC_PROFILE [1 – 11]

A random topology is considered where a total of 30 nodes are simulated and analysed. The transmission range is defined as 250 m and the number of radios varies from 1 to 5 per node using

ns-2 simulation. A central controller BS is created along with subordinate SS's where the number of sufficient or insufficient channels has an impact on the multi-radio network. In the case of centralized scheduling, BS takes control as a centralized entity and all activities of SS's are maintained and monitored by it. In this scheduling mechanism, CA strategy is provided that is responsible for utilizing minimal number of channels. Based on the number of channel usage, following cases could occur.

Case (a): Sufficient number of channels:

A minimal number of channel utilization in the network is provided by avoiding co-channel and co-located radio interferences, where channel utilization is calculated and throughput optimization is considered. Here an MRMC network is assumed, where links can be assigned a minimal number of channels. With the existence of a sufficient number of channels, an appropriate channel allocation scheme could be employed to eliminate interference entirely, by avoiding co-located radio interferences. There are three types of methods such as direct, induction and contemporary methods [31] [32]. Where the induction method examines that the sufficient number of channels condition is true. The deduction method examines that the sufficient number of channels condition is false. Direct method generalizes the condition of sufficient number of channels.

For this kind of network, the following case (a) is proven with the method of induction as,

$$(a + b)^T = a^T + b^T \text{ where } n = 1, 2, \dots N.$$

Here 'T' is considered as time, and then all the packets first exist in the base station BS at T = 0. At n = 1, then induction method as $(a + b)^1 = a^1 + b^1$ then the packets move to the level 1 and the packets to level 2 as,

$$(a + b)^2 = a^2 + b^2 + 2ab \text{ where } ab \text{ and } ba \text{ have interference as NULL}$$

$$(a + b)^2 = a^2 + b^2 \text{ \&\& } (a + b)^3 = a^3 + b^3$$

Based on level 3, hop count three is assigned as the highest for all the packets between the source and destination. At time T = k, with the sufficient number of channels, the hop count is created to be 2 and also for T = k+1 based on the induction method. Two packets with the levels T and T-3 at T = k+1 are considered; then the difference is 1 for hop count. So level 'i' is selected for transmission, which has no interference while T = k has hop count difference of 2. Based on the induction method,

$$(a + b)^k = a^k + b^k \text{ \&\& } (a + b)^{k+1} = a^{k+1} + b^{k+1}$$

This case is valid for all the channels and applied to all the networks.

Case (b): Transmitter / Receiver based interference free channels

[39] explains the contemporary methods if the condition is proved to be false for the sufficient number of channels. Based on the contemporary method, this case is false for this network because this network supports multi-radio transceiver i.e. interference avoidance is negligible for further co-channel avoidance. So, the function f(T) and f(R) where Transmitter 'T' and Receiver 'R' are neglected.

Case (c): Insufficient number of channels

If the condition of insufficient number of channels is true as in [39], CA algorithm is used to avoid

interference. With the Graph $G(E, V)$, a Line graph $L(V, E)$ is first constructed. Then, independent subsets are identified based on the min-max degree of a node and hop count for interference avoidance to assign channels in the network. With the interference results, Path graph P_n is then created from $L(V, E)$ to achieve subset for interference avoidance and to provide a minimal number of channels in the network. This procedure makes the decision to carry out this case for an insufficient number of channels.

5.1 Variation in the number of channels with different QoS parameters

In this section, we have compared proposed Ra-CA with the existing algorithms namely, BFS-CA [19] and MaIS-CA [20]. With the channel variation, the Probability Delivery Ratio (PDR) is calculated from equation (3) [28]. The proposed Ra-CA has more marginal increase than the existing one for all the variations up to 5 channels. The proposed Ra-CA and the existing BFS-CA have a slight variation, as an increase in the number of channels is represented in Fig. 4(a).

$$\text{Probability Delivery Ratio (PDR)} = \frac{\text{Number of packets received}}{\text{Number of packets sent}} \quad \text{---- (3)}$$

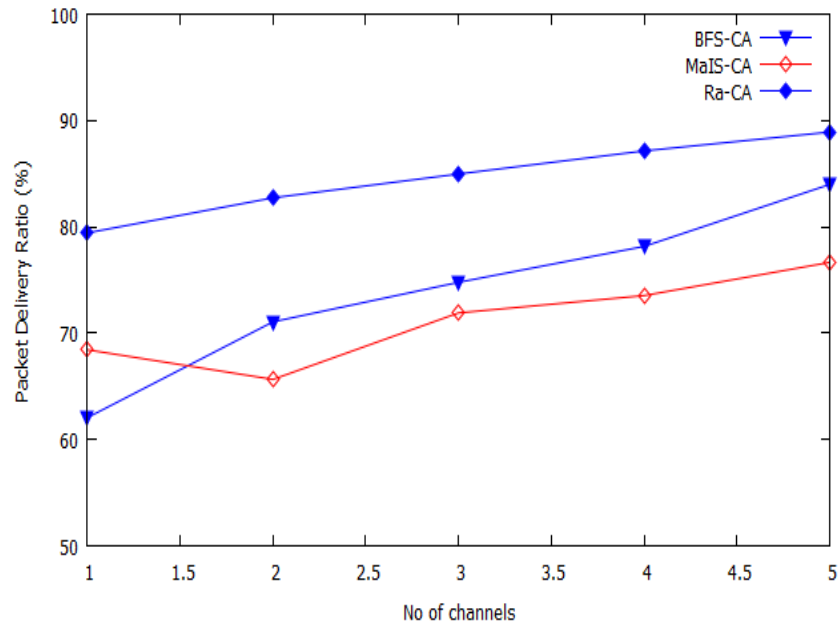


Fig. 4 (a) Packet Delivery Ratio Vs Number of Channels

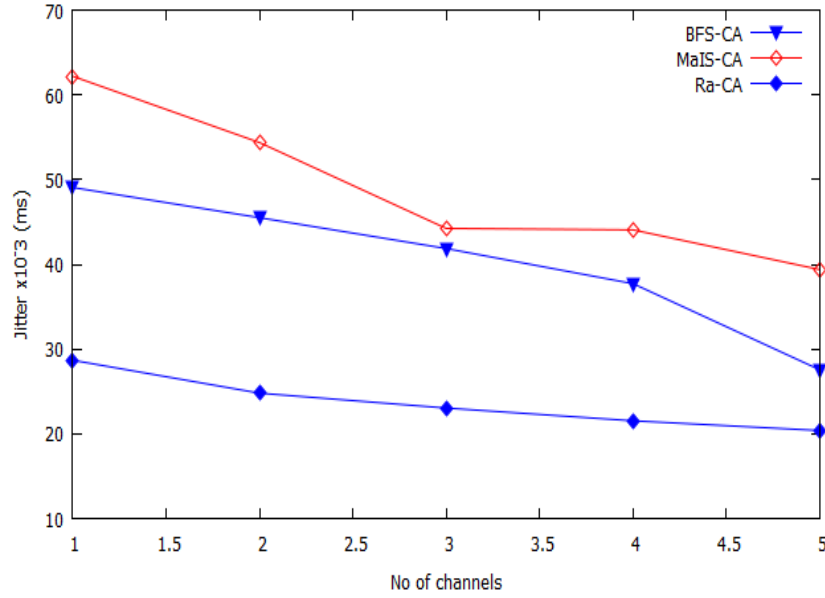


Fig. 4 (b) Jitter Vs Number of Channels

When the sender side transmits packets, any variation in the delay of received packets is considered as jitter and is given in equation (4) [28]. Based on the determination of notation used in equation (3) [29] for PDR, the proposed Ra-CA decrease time interval at the destination, when compared to the existing algorithms represented in Fig. 4(b).

$$\text{Jitter} = \text{Actual Transmission Time} - \text{Expected Transmission Time} \quad \text{---- (4)}$$

In case of the proposed Ra-CA scheme, delay is calculated for varying number of channels and is shown in Fig. 5(a). As the number of channels range from 1 to 5, the delay decreases with 30 nodes being analysed. The transmission delay decreases gradually with the minimal number of channels limit. However, as the number of channels get increased with over channel usage, the transmission delay seem not to maintain this gradual decrease. The transmission delay, given by equation (5), is calculated based on the number of packets sent with the starting time and finishing time.

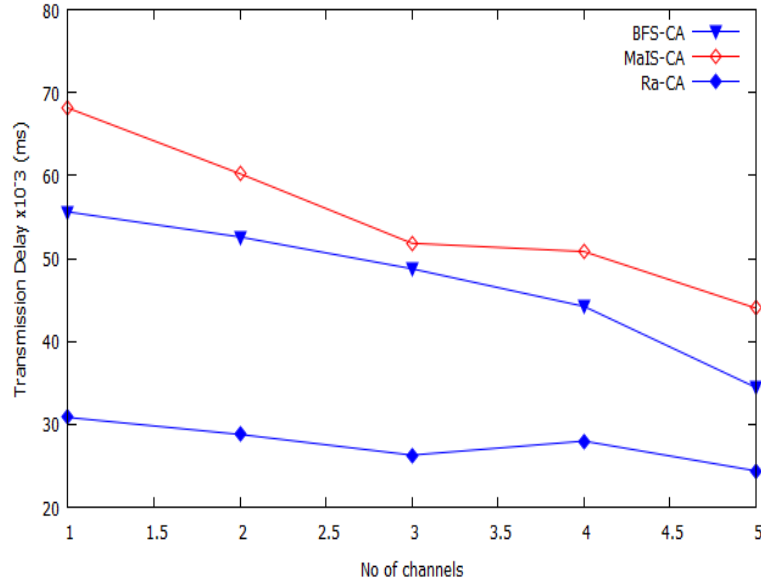


Fig. 5 (a) Transmission Delay Vs Number of Channels

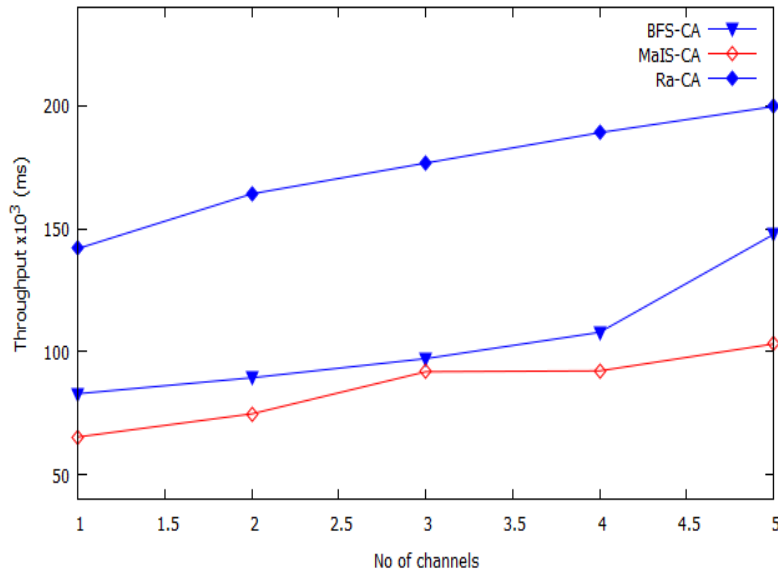


Fig. 5 (b) Throughput Vs Number of Channels

$$\text{Transmission Delay} = \frac{(\text{FinishedTime} - \text{StartingTime})}{\text{Number of packets sent}} \quad \text{---- (5)}$$

In Fig. 5(b), BFS-CA and MaIS-CA have little difference based on the throughput of the network. However, the proposed Ra-CA scheme has a gradual increase in the throughput based on the variation in the number of channels, and is given by equation (6) [30]. For the same delay parameter, as in Fig 5(a), throughput also increase with the exact channel utilization count. The channel gets increased, but the throughput maintains its stable level in Fig. 5(b).

$$\text{Throughput} = \frac{\text{Number of packets recieved} * 8 * 512}{((\text{FinishedTime} - \text{StartingTime}) * \text{Probability delivery ratio})} \quad \text{---- (6)}$$

5.2 Comparison of the proposed strategy with heterogeneous networks scenario

The proposed Ra-CA strategy is implemented with configurations as discussed in Table. 1. In Fig. 6(a) and 6(b), the proposed Ra-CA strategy is also implemented with WiMAX + LTE as heterogeneous networks. In this heterogeneous network, the network is provided with several LTE agents like dmagent, enbagent, lteagent, mmeagent, ulsagent, etc. to analyse the performance based on delay and throughput. Simulation time is the time required to complete the individual process or task in an estimated time.

In Fig. 6(a), delay gets decreased in Ra-CA (WiMAX + LTE) when compared to Ra-CA (WiMAX) based on the variation in the simulation time. In Fig. 6(b), throughput gets increased in Ra-CA (WiMAX + LTE) when compared to proposed Ra-CA (WiMAX) with the difference in the simulation time.

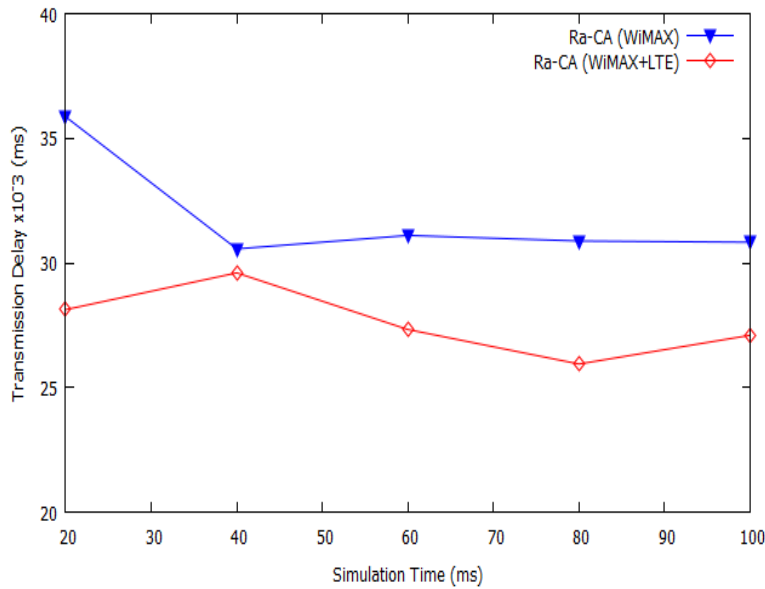


Fig. 6 (a) Comparison of the Number of Channels with the Transmission Delay

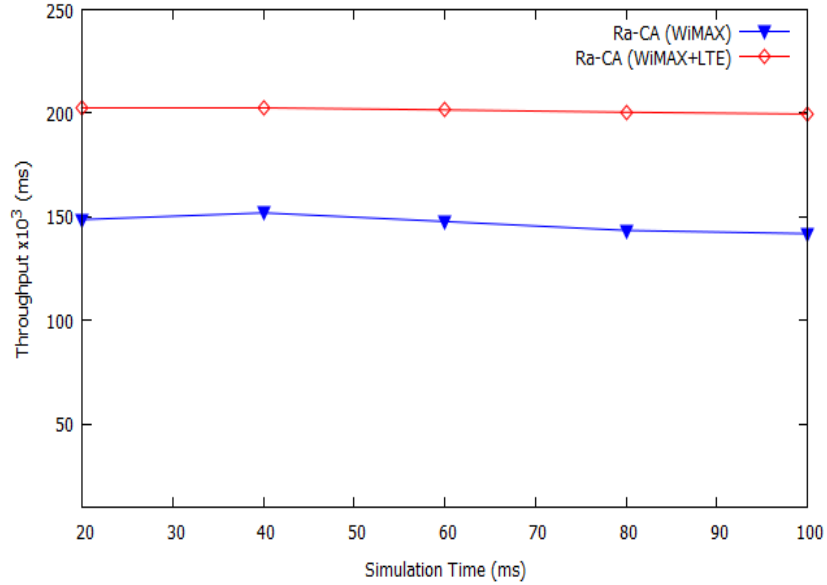


Fig. 6 (b) Comparison of the Simulation Time with the Throughput

5.3 Effect of QoS based on the simulation time

In this section, the QoS parameter is analyzed for varying simulation time against channel usage count of 1 and 5. The channel count is fixed for the proposed Ra-CA and is compared with the existing BFS-CA and MaIS-CA

As shown in Fig. 7(a), the transmission delay reaches a steady level as simulation time increases. At the initial simulation time 20 ms, the proposed Ra-CA gets little variation compared to the existing algorithms, but as the simulation time increased, delay variation gets increased with the existing BFS-CA and MaIS-CA algorithm.

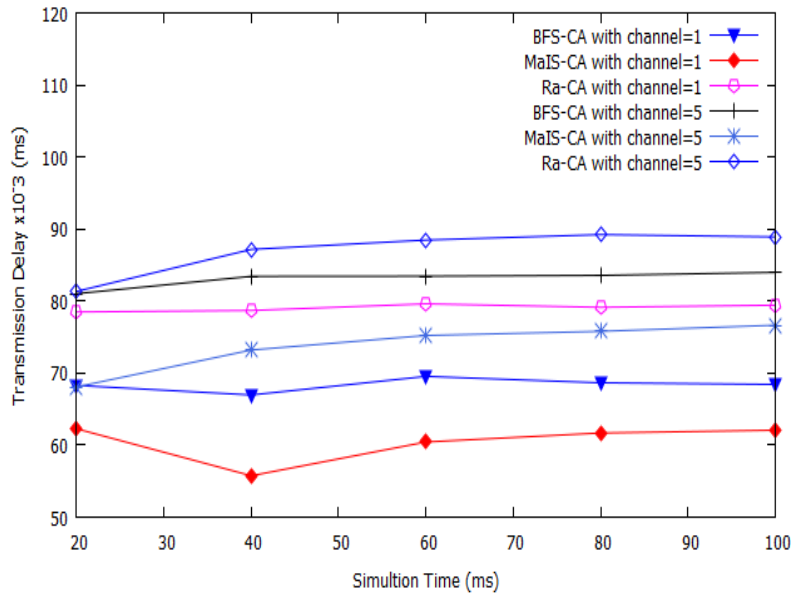


Fig. 7 (a) Simulation Time Vs Transmission Delay

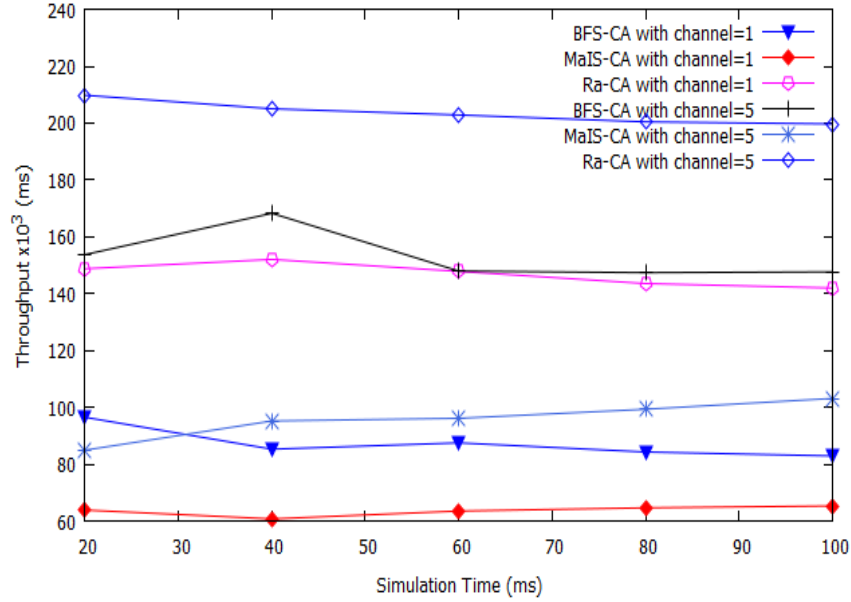


Fig. 7 (b) Simulation Time Vs Throughput

With the channel count of 5, the existing BFS-CA and MaIS-CA have a slight variation based on the simulation time, but the proposed Ra-CA has increased throughput with constant level with the simulation time difference. As same as in Fig. 7(a), throughput also increased with the number of channel usage count as in Fig. 7(b).

On the base of these simulation results, we can clearly claim that proposed Ra-CA is better than existing algorithms namely BFS-CA and MaIS-CA in terms of QoS parameters such as, packet delivery ratio, packet drop, transmission delay and throughput. This work can considerably benefit advanced networks like LTE and heterogeneous wireless networks.

6. Conclusion

Based on CA strategy, the Ra-CA algorithm is proposed in a multi-radio multi-channel mesh network. Our strategy involves a minimal number of channels with the avoidance of both co-located radio and co-channel interference when compared to the existing algorithms such as BFS-CA and MaIS-CA. In the simulation, the effect of QoS parameters based on channel variation is studied which helps to analyse the performance of Ra-CA algorithm. The variation in the number of channels is observed for the proposed Ra-CA with the increased amount of QoS services i.e. packet delivery ratio, packet drop, transmission delay and throughput. Ra-CA strategy is compared with the number of channel usage with the avoidance of co-located radio interference. Compared to the existing schemes, the proposed algorithm provides a radio based interference aware resource allocation with increasing network throughput. The proposed algorithm supports uplink/downlink. In the future study, this problem can be addressed in Next Generation Networks such as 5G Heterogeneous Networks (HetNets) as it provides multi-radio concept i.e. OFDM and performance analysis and future directed towards the distributed scheduling are to be considered

Acknowledgements

Ramkumar Jayaraman gratefully acknowledges support from Anna University - Anna Centenary Research Fellowship. Gunasekaran Raja, Ramkumar Jayaraman gratefully acknowledges support from NGN Labs, Department of Computer Technology, Anna University, Chennai.

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