International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-3, Issue-11)

Research Article **November 2014**

Evaluation of Interference-Aware Channel Allocation Algorithms for Wireless Mesh Networks

K. Venkata Subbaiah
Research Scholar
Department of CSE
S V University, Tirupati, India

Dr. M. M. Naidu
Professor in CSE
Department of CSE
S V University, Tirupati, India

Abstract-

One of the recent interest area of communications is Multi-hop wireless communication network that is used since the last decade onwards. This type of networks mainly classified into twodifferent types, they are MANETS: mobile ad hoc networks and WMNs: Wireless Mesh Networks.A mobile ad hoc network is a infrastructure less wireless networks and it is a non-hierarchical networks where all the nodes works like routers and gateways etc., all are the devices are functioning on mobility. Thenetworks, WMNs working based on infrastructure its network entities forms the hierarchical structures. WMNs used in variety of applications ranging from broadband home networking to community networks of high-speed MANs. WMNs provides the services like robustness to node failures, ease of maintenance and deployment and low deployment cost.

To improve the network performance and throughput, one of the solution proposed by researchers in the literature is adding of multiple channels and multiple radios in WMNs. Various algorithms and approaches are dedicated to maximize the network performance in MC-MR WMNs. One of the major problem facing in WMN is the capacity and throughput reduction due to interference among communication links in the wireless network. In this paper we proposed two new channel allocation algorithms are BFS-MaxNI, BFS-MinNI to minimize the interference for WMNs. We compare the results of the proposed CA-algorithms with the existed algorithms proposed by various authors in literature like BFS-CA, CCA, and CLIQUE. We considered the co-location interference between the radios and measure the interference degree value of various grid sizes and evaluated the performance of various algorithms.

Keyword- BFS-CA, CCA, CLIQUE, WMN

I. INTRODUCTION

Wireless Mesh Network (WMN) is an infrastructure based multi hop relay wireless communication network that has been used in many enterprise/real life application where we need seam less connectivity between the users. It also used in many broad band services like Internet access, mobile telephony, campus and public safety networks. With features of mesh and multi hop topology, the WMN architecture consists of three levels of hierarchy, in the Top level hierarchy that contains one or more gateways to forward the traffic to/from the Internet by wired network. The intermediate level hierarchy consists of many mesh routers which are connected wirelessly in the wireless mesh network. The mesh routers seems to be the vertices in the mesh topology and relay the traffic between all the nodes in the network. At the bottom or low level that contains many mobile clients depends on the usage of wireless mesh networks. Generally in the study of research in WMNs, most of the researchers are focused on the issues of mesh routers (nodes).

The initial architecture of WMN consist of only one radio (wireless interface card) is equipped at each node and all nodes share a single channel. However, research finding that the capacity per node in such solutions drop significantly with the increase of network size [A. Das]. Due to this WMNs suffers low throughput and unfairness problem.

Due to the observation, the single-radio single-channel architecture is not suitable for the real life applications. Single radio multi-channel architecture also considered undesirable because of the following two reasons. First, with only a single radio, a node has to change its channel frequently with the dynamic network traffic so as to fully exploit the multi-channel advantage. Unfortunately, channel switching involves non-negligible delays. Second, to reduce interference in the wireless networks a single radio assigned to different channels, in this case nodes in WMNs suffer low connectivity and even disconnectedness. Consequently, it is difficult to provide fault support.

The current and latest developments of WMNs uses Multi radio multi-channel (MC-MR) architecture, where each node is equipped with multiple radios and can use multiple-non overlapping channels like shown Figure 1. The fig show that MC-MR wireless mesh network Architecture.

The MC-MR architecture is practical due to following reasons

i. The cost of the wireless interface cards has dropped rapidly
ii. The current IEEE802.11 and 802.16 standards both support multiple non-overlapping channels.
iii. For instance, there are 12 non-overlapping channels with 20 MHz center frequency spacing in IEEE 802.11a for IEEE802.16, it utilizes radio frequencies of both licensed and unlicensed bands from 2 GHz to 66 GHz with a flexible channel bandwidth, so it can support significantly more non-overlapping channels that IEEE 802.11 [K. Ramachandran].

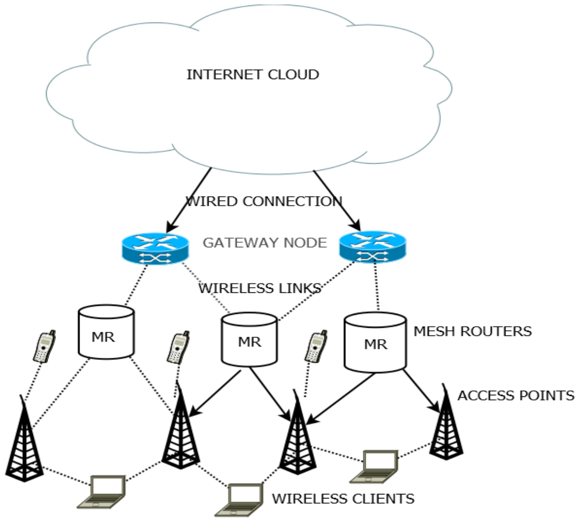


FIGURE 1 : MULTI CHANNEL MULTI RADIO WIRELESS MESH NETWORK

Therefore, the availability of multiple non-overlapping channels is not an issue as far as the standardization is concerned.

Through the extensive real-world experiments that there actually exists significant interference between these standard non-overlapping channels in the current commodity of IEEE 802.11 hardware. Nevertheless, Paul et al. also pointed out that his problem can be resolved by using better frequency filters in the hardware for multi-channel use.

The advantages of MC MR WMNs are obvious. With each node equipped with multiple radios, multiple transmissions/receptions can happen concurrently, which multiples the throughput. With multiple channels, neighboring links assigned to different channels can carry traffic free of interference, such that the link-layer delay can be dramatically reduced. As a result, when compared with single-radio and single-channel solution, one of the proposed solutions [B.-J.Ko] shows that its multiple-radio and multiple-channel solutions improves the network throughput up to a factor of seven, and an industry report [Raniwala] claims that its multiple-radio and multiple-channel solution improves the network throughput by a factor of five.

All the above advantages cannot be get until unless a number of issues solved properly in MC-MR WMNs are handled properly. Generally, these issues include node deployment, channel assignment, link scheduling, and routing. Among all these, the Channel allocation which aims to optimize the MC-MR WMNs performance by seeking a proper mapping between the available channels and radios at every node, has received extensive attention. The channel allocation issues is important due to the following reasons.

i. It is one of the new research area in WMNs.
ii. It solves the operational problems of WMNs.
iii. It is one of the challenging task to the researchers to formulate the Channel allocation problem turn out to be NP-hard.

Therefore, here we concentrated on channel assignment issue and gathered in-depth information about to various approaches to address this problem. This paper is organized as follows: we elaborated the effect of channel assignment and related work on network in Section II. Explain the proposed work in section III. We formulate channel Assignment Problem in Section IV. Interference Estimation in MCMR conflict graph explained in Section V. Explain our proposed Algorithms in Section VI. Simulation based evaluation results and compared with other approaches discussed in Section VII and concludes the paper in Section VIII.

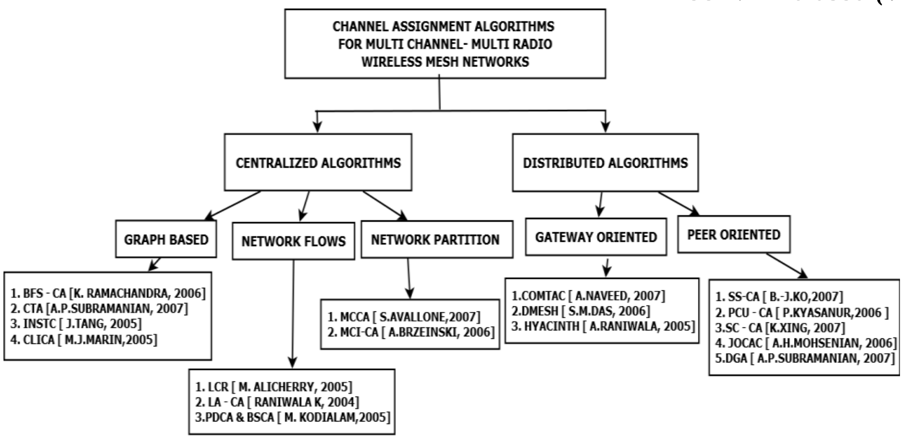
II. RELATED WORK

In the literature, many protocols and methods were proposed to improve the capacity of multi-hop wireless networks like WMNs and AWNs by avoiding interference between adjacent wireless links. In [J. So 2004] [A. Nasipura 1999] and [K. Ramachandran 2006], the authors concentrated on the use of multiple non-overlapping (i.e., orthogonal) channels over a single radio interface. These procedures require a quick and efficient algorithm to switch the radio's operating channel dynamically. [Ian F.Akyildiz 2004] gives an excellent survey of WMNs.

Generally the existing channel allocation algorithms for Multi-channel Multi Radio Wireless mesh networks are classified into as shown in the Figure 2.1. The existed channel allocation algorithms aim is to maximize the network throughput and to minimize the overall interference.

The existing channel allocation algorithms for MC-MR WMNs are mainly classified into two categories, they are **centralized** and **distributed algorithms**. In the **Centralized Channel Allocation Algorithms (CCA)**, a central controller exists and it has the complete information about the wireless mesh network. The formulated Channel Allocation Problem can be solved at a single place. A channel allocation algorithm has to determine which channels to be assigned to which radio links and distribute this information to various nodes in the network. Existing centralized channel allocation algorithms are classified into graph-based, network-flows and the network partition based algorithms. The existing **centralized channel allocation algorithms** are explained in detail in the Section II.1.

ISSN: 2278-9359 (Volume-3, Issue-11)



FIRUGRE 2.1 : CLASSIFICATION OF VARIOUS EXISTED CHANNEL ALLOCATION ALGORITHMS

In other approach, no central controller exists and every node in the wireless mesh network runs on its own algorithm to allocate the channels to its radios. The existing **distributed channel allocation algorithms (DCA)** are classified broadly into two categories according to their traffic pattern, they are **Gateway** and **peer-to-peer oriented** approaches.

In the Gateway approach, the total traffic is forwarded to or from the gateway only, so the channel allocation algorithms can use a relatively high bandwidth wireless link channels near to the gateway node. Next, in the peer to peer oriented approach, there is no fixed network traffic pattern between any pair of nodes, so the channel allocation approaches have to be as a general procedure to assign various types of network traffic pattern.

In the CCA approach, By considering of the input parameters, and output of the objective and heuristic or approximation method, these centralized algorithms are classified into **i) Graph based ii) Network flows and iii) Network partition** based approaches.

II.1 Graph Based centralized channel allocation algorithms

In this approach, a Multi-Channel Multi Radio Wireless Mesh Networks is considered as a graph with a set of vertices and edges, and the various channel allocation algorithms are used to assign channels to the vertices or edges of the network graph. In this category, generally there are mainly three types of graph theoretic concepts are used they are: Conflict Graph, Network Topology and Unit disk graph. The conflict graph based channel allocation algorithm that was first introduced in Wireless Mesh Network context is given in [K. Jain].

The following four approaches belong to this category:

i) BFS-CA (Breadth First Search Channel Assignment used in [Ramachandran, 2006])
ii) CTA (Centralized Tabu based Algorithm used in [A.P. Subramanian, 2007])
iii) INSTC (Minimum Interference Survivable Topology Control used in [J. Tang, 2005])
iv) CLICA (Connected Low Interference Channel Assignment [M.K. Marina, 2005])

i) BFS-CA (Breadth First Search – Channel Allocation)

This approach proposed by [K.Ramachandran, 2006] to design an efficient channel allocation algorithm for Multi Radio Multi Channel Wireless Mesh Networks. In this approach they designed a Multi Radio Conflict Graph (MCG) by extending of traditional conflict graph by splitting the multiple radios at each node. The MCG differs in two ways than the other methods i) in this they considered each radio as a separate vertices ii) in this the interference modeling can be done by using unit disk graph instead of network topology. In this approach they constructed a Multi Radio Conflict Graph by using protocol model at the beginning of the algorithm to assign the channels to the vertices. The construction of Multi Radio conflict graph as shown in the Figure 2.2 (a), Figure 2.2(b) and Figure 2.2(c).

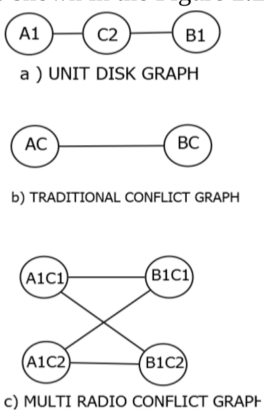


Figure 2.2: Construction of Multi Radio Conflict Graph from the Unit Disk Graph

The Figure 2.2 (a) shows a unit disk graph that contains the nodes A and B with single radio and C contains two radios. The Figure 2.2 (b) is a traditional conflict graph of assuming C as a single node, but in general to improve the performance of the network we add multiple radios to a node, Due to this adding of multiple radios in the node the interference becomes more. The minimization interference, improves the network throughput. The Figure 2.2 (c) shows a separated multi radio conflict graph.

In BFS-CA [K.Ramachandran, 2006] work the following assumptions are made on multi-channel and multi radio wireless mesh networks.

i) A central node (gateway) is used to monitor the traffic to / from the internet
ii) A server running on the gateway (CAS – Channel Allocation Server) and its job is to collect information from all the nodes and Compute the Channel Allocation and distribute the results to all the nodes in the network.
iii) Every node in the network assign a default radio that running on common default channel to carry both data and control packets.

The main objective of this approach is to minimize the interference among the mesh routers and in between of MC-MR WMNs and external co-located wireless networks. The main advantages of this approach is i) a novel MCG is proposed such that it is a straight forward method of considering the number of radios at each node in formulating Channel Allocation problem ii) A central point that is gateway used to monitor the traffic to or from the Internet. iii) it is the first algorithm considering the external interference iv) it is practically demonstrated in multi-radio IEEE 802.11b test bed. The limitations of this BFS-CA is i) its heuristic mechanism to reduce both internal and external interference by combining the channel ranking and the MCG constraint is intuitive, providing no known bound for the worst-case performance; ii) The gateway acts as central point of the network traffic.

ii) CTA (Centralized Tabu based Algorithm)

This approach proposed by [A.P. Subramanian, 2007], in this they considered the Conflict Graph to assign the channels to the vertices with the aim of to minimize the total network Interference. In this method they considered the number of channels, number of radios at each node, and conflict graph as input parameters. They assigned a constraint to each node to assign the channels cannot exceed the number of available interfaces. To find a solution to the Channel allocation, in this the CTA formulated as Max K-Cut problem, it is defined as the set of vertices of the given graph G, are partitioned into k-subsets such as the number of end point of the links belong to different partitions is maximized. In this, the vertices of the conflict graph are assigned a certain channel to see there in one partition, the number of total links whose end point belong to the same partition is considered as total interference of the network. The problem of Max K-cut with added constraint of interface is NP hard. CTA rearrange with Tabu search (genetic heuristic mechanism) to solve it with in polynomial time. The advantage of this is it very close to lower bound of value of total network interference. The disadvantage is it can failed to consider multiple link scenario, but it works only one modeled between each pair of nodes by assigning the channels to the vertices of the conflict graph.

iii) INSTC - (Minimum Interference Survivable Topology Control)

This approach is proposed by [J. Tang, 2005] used in INSTC. To represent wireless mesh network in this method they considered unit disk graph. To minimize the interference they introduced two metrics one is LCI (Co-channel Interference) to a link in the network topology. The term LCI defines the number of links that interfere with this link in the network. And another LPI (Link potential Interference) is defined as the number of links that interfere with this link in the unit disk graph by its interference range. The considered unit disk graph G contains number of radios Q at each node, integer K, and the number of available channels C, to assign channels the network topology T satisfy the following two objectives

- The topology is a K connected network to survive node failure or link failure
- To minimize the interference in terms of that maximum LPI for all links in T is minimized.

INSTC is a heuristic polynomial time algorithm to assign the channels by traversing links of the k connected sub network of unit disk graph in the predetermined value of LPI of each link. In this approach the links of the unit disk graph are sorted in decreasing order of their LPI values for traversing to assign the channels. The advantage of this approach is that it is prove that it is a polynomial time algorithm that achieves k-connectedness by this it obtains robustness network topology.

iv) CLICA - (Connected Low Interference Channel Assignment)

A polynomial time algorithm proposed by [M.K. Marina, 2005] to assign the channels in MC-MR wireless mesh networks. To minimize the interference they proposed a base channel assignment to preserve the network topology of any link by assigning non-overlapping channels to different links. They considered a unit disk graph for this implementation to assign the channels efficiently. In this approach, they assign a highest priority to a randomly chosen node V, then assign the priorities of other nodes in decreasing order in order to obtain depth first searching. While traversing the nodes in decreasing order of their priorities and assign the channels to the links in the unit disk graph. The main advantages of this algorithm are i) it is easy to implement ii) connectivity preservation. The main disadvantage of this algorithm is it is difficult to model the number of radios at each node.

III. PROPOSED WORK

Wireless networks face interference problems with multiple simultaneous transmissions. When two nearby links (aka node pairs) want to communicate on the same frequency band (aka channel), they cannot transmit data successfully by sending data simultaneously. As a result, the throughput of each link may be decreased dramatically due to the interference from other interfering links. In a WMN, mesh routers cannot transmit and receive simultaneously with a single radio as they employ CSMA based 802.11 Wi-Fi radio cards. To eliminate this problem, the mesh routers could be equipped with multiple radios, which can be configured to operate on different channels. The allocation of radio to a channel can be done with the help channel allocation algorithms. Thus, mesh routers are able to transmit and receive data simultaneously in MCMR WMNs without facing any interference.

In a WMN, several routers will be communicating with their neighboring routers at any point in time and thereby will achieve some sense of parallelism in communication. i.e., enabling simultaneous transmissions of data packets between several multiple sender-receiver pairs. Since WMNs operate over a shared wireless broadcast medium, such parallel transmission is fundamentally limited by signal interference, i.e., the nature and amount of interference caused by simultaneously operating transmitter-receiver pairs. This interference in the network determines the amount of parallelism that can be truly achieved and consequently the maximum achievable network throughput. The interference in the network and its collective throughput are inversely proportional. Thus, higher the number of interfering links, lower is the overall throughput in WMNs. It is important to study the extent of interference in WMNs and its impact on the network throughput. If parallel transmissions occur on different orthogonal channels, interference can be eliminated. But that will require having a large number of orthogonal channels and a set of multiple radios on each node. Since, the number of orthogonal channels is limited and the number of radios on a node is also limited due to constraints of network cost, the only solution is to have a feasible and efficient channel assignment scheme for the WMN with a small predetermined number of independent orthogonal channels and a limited number of radios on each mesh router node.

In this paper we focused on the development of efficient channel assignment algorithms with topology preservation in MC-MR WMNs. The problem of channel assignment can be informally described as follows: Given a WMN of router nodes with multiple radio interfaces, we wish to assign a channel to each wireless link in the network in such a way that if there is an edge between two wireless links in the corresponding conflict graph (which models interference between mesh routers in a very efficient manner), then these two links will be assigned different orthogonal channels. We assume that uniform traffic on all links and define the total network interference as the sum of the number of wireless links that interfere with each wireless link in WMNs. This quantity is a measure of the interference and it has detrimental effects on the network. Our objective is to minimize the total interference experienced in WMNs. Minimizing the total interference in a network will ensure an increase in the overall network capacity and a reduction in transmission loss and delay.

IV. CHANNEL ASSIGNMENT ALGORITHM

Here we proposed the channel assignment problem for Wireless Mesh Networks, which contain all important elements of a WMN can be represented as a graph. A *graph, G = (V,* E) is defined as a set of vertices *V* and a set of edges *E.* where the set E $\subseteq$N×N contains the network edges. The sets *V* and *E* have to be nonempty and finite. An edge is a link between two vertices, which joins the vertices *i* and *j*, and is denoted by (*i, j*). The vertices *i* and *j* are the end-vertices of this edge. If an edge exists between two vertices, then these two vertices are called adjacent or neighboring vertices of *G*. Two edges are called adjacent if they have one common end-vertex.

Here we need a notation to specifically represent the channel assignment. If there are *K* orthogonal channels available, without loss of generality we can use the set of integers K = *{*1, 2, . . . ,*k}* to denote them. For all $i \in$N, we denote with r(*i*) the number of NICs owned by node *i*. The exact channel assignment is represented by an *interface allocation variable* denoted as $y_q{}^i$, where $i \in$N and $q \in$K, which is a binary variable equal to 1 if node *i* has a NIC tuned on channel *q* and 0 otherwise. Note that$\sum_{q=1}^{k} y_i^q = r(i)$for all nodes $i \in$N. Similarly, if *i, j* $\in$N and $q \in$K, we define a binary *channel edge variable* called $x_{ij}^q$and defined as equal to 1 if *i* can transmit to *j* using the *q* the channel, and 0 otherwise.

V. INTERFERENCE ESTIMATION AND MODELING

In this section we presents an overview of the interference estimation procedure by using Multi-radio Conflict graph.

A. Interference Estimation

The objective of this interference estimation is to measure the interference level in each mesh router's environment periodically. Accurate measurement, is a challenging task in WMNs to estimate and to find suitable channel allocation algorithm with aim of to minimize interference to maximize the network capacity and throughput.

B. Interference Modeling

Generally the Conflict graphs are used extensively to estimate the interference wireless networks. To design a conflict graph for a mesh network is defined as follows: consider a graph, G, with nodes corresponding to routers in the mesh and edges between the nodes corresponding to the wireless links. A conflict graph, F, has vertices corresponding to the links in G and has an edge between two vertices in F if and only if the links in G denoted by the two vertices in F interfere with each other.

In the literature, the authors consider the conflict graph for interference estimation in WMNs. The conflict graph, for a simple MRMC Network as shown in Figure 2, Figure3, and Figure 4, as show an example of the same for a 4-node network graph

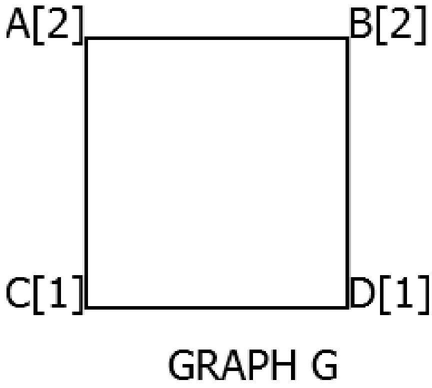


Figure 2: Example of a multi radio graph for WMN

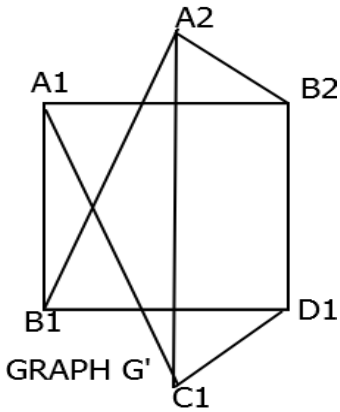


Figure 3: Separated multi radio graph for Figure 2

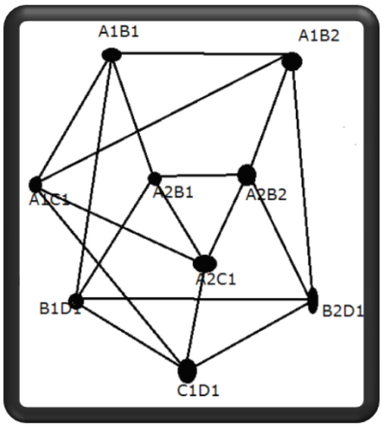


Figure 4: Conflict graph for Figure 3

VI. PROPOSED ALGORITHMS

In our algorithm, called the Breadth First Search Maximum Neighbor Index Channel Assignment (*BFS-MaxNICA*) algorithm, uses a breadth first search to assign channels to the mesh radios. The search begins with links emanating from the gateway node. The use of breadth first search is intuitive: by using breadth first search, we satisfyour goal described in Section III of giving channel assignment priority to links starting from the Gateway and then in decreasing levels of priority to links fanning outward towards the edge of the network. Before using the BFS-MaxNICA algorithm, the channel assignment server (CAS) obtains the interference estimates from the mesh routers. It then chooses a channel for the default radios. The default channel is chosen such that its use in the mesh network minimizes interference between the mesh network and collocated wireless networks. The CAS then creates the MCG for the non-default radios in the mesh. We use a two-hop interference model to create the MCG. In this model, two mesh links are interfering if they either have a common router or are separated by a hop as determined from the neighbor information sent by each mesh router to the CAS. This technique can be more accurate because of its empirical nature, however, takes a long time (several hours) to complete. We are currently investigating approaches to speed up this technique. In the meantime, we leverage the two-hop model in our work.

After constructing the MRCG, the CAS uses the BFS-MaxNI CA algorithm to select channels for the non-default radios. Once the channels are selected for the mesh radios, the CAS instructs the routers to configure their radios to the newly selected channels. To
Simplify the explanation of the channel selection procedure in this section, let us assume that the mesh radios are

Algorithm 1: BFS – Maximum Mutual Neighbor Index

Step 1: Do the BFS Traversal
Give the priority to highest degree node during traversal.
Every Node in the same BFS level will be sorted according to their degree (decreasing order).
Step 2: k ←1 where k∈ {1, 2, and 3…k}
for each j ∈I do
Assign all the nodes in the level I, channel k
k←k % 3 + 1
end for
Step 3: for i = 0 to max level do
Step 4: previous node = 0
Step 5: for each node v in level i do
Step 6: If previous node = 0 then
Step 7: Pick a node v with maximum degree among all nodes.
Step 8: else
Step 9: Pick a node v which has maximum Mutual Neighbour Index with previous node.
Step 11: end if
Step 12: For node v calculate the interference degree and assign the channel for which it has minimum interference degree
Step 13: previous node = v
Step 14: end for
Step 15: end for

reconfigured at the same time.
si

Algorithm 2: BFS – Minimum Mutual Neighbor Index

Step 1: Do the BFS Traversal
Give the priority to highest degree node during traversal.
Every Node in the same BFS level will be sorted according to their degree (decreasing order).
Step 2: k ←1 where k ∈{1, 2, and 3}
for each j ∈I do
Assign all the nodes in the level I, channel k
k←k % 3 + 1
end for
Step 3: for i = 0 to max level do
Step 4: previous node = 0
Step 5: for each node v in level i do
Step 6: If previous node = 0 then
Step 7: Pick a node v with maximum degree among all nodes.
Step 8: else
Step 9: Pick a node v which has minimum Mutual Neighbour Index with previous node.
Step 11: end if
Step 12: For node v calculate the interference degree and assign the channel for which it has minimum interference degree
Step 13: previous node = v
Step 14: end for
Step 15: end for

VII. PERFORMANCE RESULTS

The objective of the simulation-based evaluation is to understand the behavior of our *BFS-MaxNICA&BFS-MinNICA*algorithms ondifferent grid based networks. We consider three large-scale grid based topologies. We calculate interference degree in three different network scenarios by applying CCA, Clique and BFSCA Algorithms. In our evaluations, we compare *BFS-MaxNICA&BFS-MinNICA*against a static channel assignment of BFSCA, CCA and Clique algorithms. The simulation results show that proposed scheme outperforms the earlier approaches with respect to interference degree.

We consider the following assumptions in the implementation of all algorithms

- In all the algorithms, the original topology is a grid structure.
- Every node will have two radios.
- V is the set of vertices of initial topology.
- E is the set of edges of initial topology.
- Three orthogonal channels (say 1, 2, and 3) are used for the channel assignment

Table 1: comparison of proposed CA-Algorithms with the existed CA-Algorithms

Grid Size	BFS Minimum Neighbour Index	BFS Maximum Neighbour Index	BFSCA	CCA	Clique Algorithm
3 x 3	62	84	82	100	114
5 x 5	262	266	132	340	332
10 x 10	2348	2614	2098	1640	1692

VIII. CONCLUSIONS

Multi-radio routers can significantly improve the performance of wireless mesh networks. However, any static assignment of channels to the mesh radios can degrade network performance because of interference from co-located wireless networks. This paper presented *BFS-MaxNICA&BFS-MinNICA*, a dynamic, interference aware channel assignment algorithms and corresponding protocol for multi-radio wireless mesh networks. The proposed algorithm improves the performance of wireless mesh networks by minimizing interference between routers in the mesh network and between the mesh network and co-located wireless networks. The proposed solution is practical and easily implementable. We find that BFS-MinNICA results in significant performance improvements in the presence of varying interference levels, which are validated through empirical Experiments. As future work, we plan to evaluate BFS-MaxNiCA on the small world networks [Chetan Kumar Varma].

ACKNOWLEDGEMENTS

This work is done in Indian Institute of Technology, Hyderabad under guidance of Dr. T. B. Reddy, Assistant professor, Department of CSE, as a part of my ph. D research process to fulfill the requirements of S V UNIVERSITY, TIRUPATI. In this direction, I thanks to the Director, HOD-CSE, and all the members who helped a lot to get the results.

REFERENCES

[1] [Chetan Kumar Varma] Chetan Kumar Varma, Bheemarjuna Reddy Tamma, B.S. Manoj, and Ramesh Rao, "A Realistic Small World Model for Wireless Mesh Networks ", *IEEE COMMUNICTIONS LETTERS*, VOL. 15, NO.4, April 2011.

[2] [J. So] J. So and N.H. Vaidya, "Multi-channel mac for ad-hoc networks: Handling multi-channel hidden terminals using a single transreceiver", *in proceedings of the ACM symposium on Mobile ad hoc networking and computing (MOBIHOC) 2004,* pp. 223-233.

[3] [A. Nasipura] A. Nasipura, J. Zhang, and S.R Das, "A multichannel csma mac protocol for multihop wireless networks", *in proceedings of IEEE Wireless Communications and Networking Conference (WCNC), 1999.*

[4] [K. Ramachandran] K. Ramachandran, E. Belding, K. Almeroth, and M. Buddhikot, "Interference-aware channel assignment in multi-radio wireless mesh networks", *in proceedings of IEEE INFOCOM, 2006*

[5] [A. P. Subramanian] A. P. Subramanian H. Gupta, and S.R. Das, "Minimum interference channel assignment in multi-radio wireless mesh network", *in proceeding of Fourth Annual IEEE communications society conference on sensor, mesh, and ad-hoc Communications and Networks (IEEE SECON 2007).*

[6] [B.-J.Ko] B.-J.Ko V.Mishra, J.Padhye, and D.Rubenstein, "Distributed channel assignment for multi-radio 802.11 mesh networks", *Colombia University, Tech. Rep., 2006*

[7] [Naveed] Naveed, A. Kanhere, S.S., "Cluster-based Channel Assignment in Multi-Radio Multi-Channel Wireless Mesh Networks", *in proceedings of LCN 2009*.

[8] [Minho Shin] Minho Shin, Seungjoon Lee; Yoo-ah Kim "Distributed Channel Assignement for multi-radio wireless networks", *Mobile adhoc and sensor systems (MASS) 2006 IEEE International conference*, pp. 417-426, 2006

[9] [Raniwala]Raniwala K. Gopalan, and T.Cker Chiueh, "A Centralized channel Assignment and Routing Algorithms for multi-channel WMNs", *ACM SIGMOBILE Mobile Computing and Communiacations Review*, 2004.

[10] [Saskalli] Saskalli, S. Ghose, S. K. Das, L. Lenzini, and M. Conti, "Channel assignment strategies for multi-radio wireless mesh networks: issues and solutions", *IEEE Communications Magazine*, vol. 45, no. 11, pp. 86-93, 2007.

[11] [M.K. Marina] M.K. Marina and S.R Das., "A topology control approach for utilizing multiple channels in multi-radio wireless mesh networks", *in proceedings of IEEE BroadNets, Boston, 2005. Pp. 381-390.*

[12] [A. Das] A. Das H. Alazemi, R. Vijayakumar, and S. Roy., "Optimization models for fixed channel assignment in wireless mesh networks with multiple radios", *in proceedings of IEEE Communications Society Conference on Sensor, Mesh and Ad-hoc Communication and Networks (SECON 2007), 2007.*

[13] [Ian F.Akyildiz, 2004] Ian F. Akyildiz , Xudong Wang , Weilin Wang.," Wireless mesh networks: a survey" , in Elsevier Computer Networks 47 (2005) 445–487.

[14] [K.Jain, 2003] K. Jain, J. Padhye, V.N. Padmanabhan, L. Qiu, Impact of interference on multi-hop wireless network performance, in: ACM MOBICOM, San Diego, CA, USA, 2003, pp. 66_80.

[15] [J. Tang, 2005] J. Tang, G. Xue, W. Zhang, Interference-aware topology control and QoS routing in multi-channel wireless mesh networks, in: ACM MobiHoc, 2005, pp. 68_77.

