Channel Assignment Algorithms and Strategies for Wireless Mesh Networks

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Abstract— **This research report is about providing a solution to the problem of channel assignment in the multi radio wireless mesh networks that have an ad hoc based infrastructure. The aim was to minimize the fractional interference so that throughput can be maximized. The algorithms to solve this problem were classified and explained how they work. A description of channel assignment techniques is given along with a brief comparison in the literature. Main focus was towards the use on genetic algorithm. It also gives a detailed explanation of how genetic algorithm could be implemented in order to solve this problem along with conflict graphs being made by running functions in MATLAB.**

Keywords— Multi radio, Wireless mesh networks, Ad Hoc networks, Channel Assignment, Genetic Algorithm

I. INTRODUCTION

Using multi radio wireless mesh networks gives the advantage of increasing the capacity of the network. Along with that, the non-overlapping channels make it possible for each interface of radio to run on a different channel. However, due to the limitations in the number of channels that could be assigned, channel assignment problem becomes serious. A good channel assignment scheme is required to enhance the throughput and make efficient use of such a network. This research studied some of the techniques of channel assignment but its main focus was towards the use of genetic algorithm.

II. PURPOSE OF STUDY

Today, wireless mesh networks (WMNs) are being utilized almost everywhere due to its various advantages which includes:

- Cost effective and cheaper than traditional wired networks as there are no wires used
- Easy to expand and convenient to use
- Offers self-management and self-configuration
- Setting up a wireless mesh network is easy
- Line of sight not required
- And many more.

However, the wireless technology has to face many limitations due to which throughput is affected. Throughput refers to the average number of packets that were successfully delivered to the destination. As the use of wireless mesh networks increase, the need for it to provide greater throughput is also increasing. A way to achieve this is by aggregating bandwidth of multiple connections and assigning them different non-overlapping frequency channels. With IEEE 802.11a, there are 12 non-overlapping channels available and 802.11b/g has 3 such channels. The availability of Network interface cards (NICs) at reasonable costs makes this even more possible and affordable. There are various channel assignment algorithms and schemes available after much research to allocate different channels to make parallel transmission possible. [1] [2] [3] [4] [5] [7]

This research aimed to identify the techniques and algorithms and mainly study the genetic algorithm and how it can be used to solve this problem of channel assignment. These results were to be compared against other algorithms and mechanisms available. The work of this research paper is for the wireless ad hoc based multi radio wireless networks which do not depend on the infrastructure of the network that includes routers. The nodes take part in forwarding the packets.

A. Problem Statement

"Do channel assignment algorithms based on genetic algorithm help in increasing throughput in multi-radio wireless mesh networks (Ad hoc based)?"

B. Hypothesis

The hypothesis is "The channel assignment algorithms based on genetic algorithm can help in increasing throughput in multi-radio wireless mesh networks (Ad hoc based)".

III. LITERATURE REVIEW

This section contains the review and summary of the literature studied for the research. As it is known that WMNs provide high speed internet connectivity in a very cost effective manner, which is why it has many applications nowadays. Apart from that, each node can have multiple radios and if same channels are assigned to the interfering nodes then it could have a great impact on the performance. That is why channel assignment is not an easy task. [3] [8]

This idea of wireless mesh network is not only applicable for the mesh topology networks but also the meshes having tree topology, as mentioned in [16]. It explained how the traffic could be sent from root node to the leaf nodes.

The paper [3] analyzed and identified approaches that are used for the channel assignment to the radio interfaces of multi radio WMNs.

Having multiple radios on a single node is possible due to the availability of NICs at low cost. Assignment multiple channels at different frequencies to a node can help increase in the overall throughput. An efficient channel assignment algorithm should be able to: [3] [8]

- Lower the network interference,
- Increase the overall throughput of the network,
- Appropriate utilization of the frequency spectrum to allocate channels in an efficient manner,
- Equal load distribution amongst the channels,
- Finally making sure that no network partitioning is made thus the topology is preserved.

A. Classification of Channel Assignment Algorithms

The channel assignment schemes were classified into different categories. This is identified in the figure below: [3] [9]

TABLE 1

CHANNEL ASSIGNMENT ALGORITHMS' CLASSIFICATIONS

Classification Criteria	**Types of Channel Assignment**
Channel Switching Frequency	a) Static/Fixed: ▪ Common Channel Assignment (CCA) ▪ Varying Channel Assignment (VCA) b) Dynamic c) Hybrid
Number of Radios	a) Single Radio b) Multiple Radio
Spectrum Utilization	a) Orthogonal Channels (OCs) b) Partially Overlapped Channels (POCs)
Topology Awareness	a) Centralized b) Distributed
Routing Dependency	a) Routing independent b) Routing dependent c) Joint Approach
Infrastructure	a) Access Point based b) Ad hoc based c) Hybrid approach
Granularity of Assignment	a) Per Packet Channel Assignment b) Per link Channel Assignment c) Per Flow Channel Assignment d) Per Component Channel Assignment

B. Channel Switching Frequency Fixed/Static

With this scheme, the channel is assignment for a longer time period in order to help control the nodes' connectivity. It is further divided into two categories

- Common Channel Assignment (CCA): the radios are assigned to a mutual set of channels. This provides no change in network topology, but the number of non-overlapping channels is more than radios in each of the nodes which means the throughput increase will be limited and channel utilization will not be efficient.
- Varying Channel Assignment (VCA): different sets of channels are given to different interfaces of nodes. But as the channels are not linked, so it can lead to network isolation and change in topology. CLICA (Connected Low Interference Channel Assignment) algorithm is an example. [2] [3] [4] [9]

C. Dynamic

As the name suggests, it is the dynamic assignment of the channels to the radios. The major benefit from this is the ability to utilized different channels with only less number of interfaces. However, switching delays, time synchronization and coordination are some challenges of this approach. [3] [4] [9]

D. Hybrid

This is a mixture of fixed and dynamic where some radios are assigned channels statically and others dynamically. [3] [9]

E. Number of Radios

A simple and easy to implement approach is single radio based channel assignment. However, single radio less utilization of channels, parallel transmissions not possible and channel switching is more frequent which involves its cost. [3] [9]

Multi radio is now being studied and used for WMNs which has better channel utilization, lesser channel switching and possibility of parallel transmissions but more difficult to implement. [3] [9]

F. Spectrum Utilization

The orthogonal channels or non-overlapping channels are more commonly used, however research work is being carried out to also utilize the partially overlapped channels as the orthogonal channels are only 3 (802.11b/g) or 12 (802.11a) might not be sufficient in future. [3] [7] [9] [15]

G. Topology Awareness

Centralized channel assignment are easy to implement and feasible when the network topology or routing tables are known, like in access point based networks. [3] [7]

Distributed channel assignment is for the Ad hoc based networks where the topology or global network information is not known. [3] [9] [11]

H. Routing Dependency

- Routing Independent: can work with any type of routing protocol
- Routing Dependent: only work with specific routing protocol
- Joint Approach: selects channels to the end path to optimize route [3]

I. Infrastructure

- Access point based: Centralized where all the network information is at access point.
- Ad hoc based: Distributed, where network topology information is not known that can lead to network partitioning.
- Hybrid based: It can either be centralized or distributed. [3] [14]

J. Granularity

- Per packet channel assignment: it has more overhead as processing is for each packet so it is not good for high loads.
- Per link channel assignment: assignment of a channel to a link between nodes
- Per flow channel assignment: one channel assigned to many links that come in between the path from source to destination
- Per component channel assignment: Channel is assigned to a component which is formed by intersecting links. [3] [17]

K. Basis of Channel Assignment

According to [5] and [6], routing can help in providing dynamic network capabilities therefore when considering channel assignment for multi radio wireless mesh networks the channel selection should be based on the information that is locally available. Apart from that, the assignment of the channel should be based on the physical structure as the dynamic capabilities are being handled by routing and transport mechanisms. Finally, the channel assignment should not change very frequently. This will give a more stable solution.

L. Channel Assignment Challenges

The channel assignment requires interference minimization along with better throughput but also a good connectivity. However, both of them together are not possible. Thus there is always a tradeoff between the two. If connectivity is increased, then interference is also increased which results in decrease in throughput. This is also addressed in various papers. [3] [9]

The figure below is taken from [9] which explains this tradeoff.

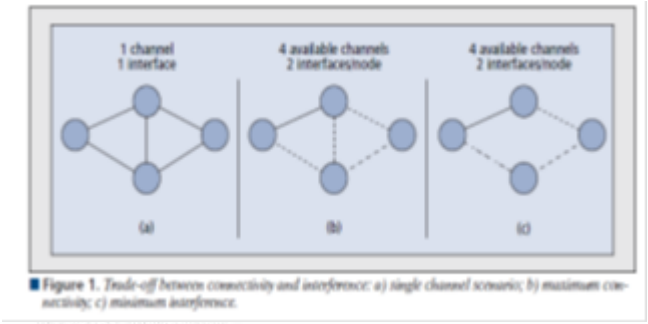

Figure 1 *Connectivity vs. Interference [9]*

M. Interference Minimization

Interference is one of the most important elements in channel assignment as it is directly linked with throughput maximization. Apart from that, the maximization of the connectivity is inversely proportional to the interference. The co-channel and adjacent channel interference needs to be taken under consideration. With co-channel interference, the use of a channel within a certain range of interference is restricted. The complete number of usable channels within a certain range can be known by adjacent channel interference. [1] [2] [3] [4] [8] [10]

N. Channel Switching Delay

The channel switching delay can have a great impact on the throughput of the network which can be in milliseconds. [3]

O. Interdependency with Routing Protocol

Channel assignment is related to the routing protocol and network information. Routing protocol defines the path of communication and channel assignment tells which channel the link will utilize to communicate. Moreover, research shows that dynamic allocation of channels with respect to the traffic has given better outputs. [3]

P. Joint Channel Assignment and Routing Problems

- Identification of a routing metric which can quantitatively tell the performance gain is important.
- Heterogeneous radios also have issues like having no common radio or channel supported for data transmission which could result in network partitioning.
- Reducing protocol overhead also introduces challenges for channel assignment and routing. [3]

Q. Using Graphs

The network topology in this case is made using a simple graph where they are connected and then made into a conflict graph. Then coloring algorithms can be used for channel assignment and mapping. Different set colors are used for different available channels and vertices of graphs are to be coloured. Following types of graphs can be used: [3] [10] [13]

- Simple conflict graph (vertices depict the nodes and edges represent the links)
- Weighted conflict graph (weights representing interference assigned to edges, used in CLICA)
- Multi-radio conflict graph (conflict graph for multi radio mesh networks, edges are between the individual radios and not nodes as a node can have multiple radios)
- Resource Contention Graph (representing capacity of multiple channels and showing the contention regions in the networks)
- Layered Graph Model (each layer represents a channel, a single node is displayed as many virtual nodes across layers) [1] [2] [3]

R. POC: Partially Overlapped Channels

As mentioned earlier that the number of non-overlapping channels are not enough so use of partially overlapped channels are being studied. However there are some challenges that need to be overcome to make it useful. The self-interference problem is one of them, due to which nodes cannot be assigned channels that are overlapping. Some interference model for this are: [3]

- Binary Interference Model: links can either be interfering or not so not good for partially overlapping channels.
- Protocol Model: An interference range is defined where the receiver can observe the interfering transmission from other channels within that boundary.
- Physical Model: Interference calculated using signal to noise ratio. The transmission is successful if the

ratio is greater than the pre-defined threshold. It is more accurate than protocol model.

- Channel Interference Cost Function: measure the level of interference of the partially overlapping channels, and as the value becomes lesser, the distribution between the channels becomes more.
- Interference factor: it also measures the level of frequency interference of channels. It uses signal power to calculate.
- Channel overlapping matrix model: also identifies the interference with the help of channel overlapping matrix.

The most challenging thing in partially overlapped channels is to adjust the signal to interference plus noise ratio (SINR), where a tradeoff is made low interference and noise will give low throughput and higher interference and noise will degrade the performance. [3]

S. Other Algorithms

1) **Random Channel Assignment.** This refers to randomly distributing channels without taking any criteria into consideration. If the nodes are connected and then the edge is randomly assigned a channel that is available. [2]

- **Greedy Channel Assignment.** All the links are assigned channels greedily. This however tries to ensure that the interference is minimum. Initially, all the links are given same channel and to minimize the interference, one link is changed at a time. So it is a multi-pass algorithm where each link can be visited multiple times. [2]
- **Clica.** It is a kind of greedy algorithm but it takes priorities into consideration. The channels are not randomly assigned or links given same channels but it assigns on the basis of priorities. The priorities are basically the number of available radios on nodes waiting for a channel to be assigned. [2] [10] [22]
- **Tabu.** This algorithm is a multi-pass algorithm with larger computation time as compared to other mentioned assignment algorithms. It initially randomly assigns the channels to all the links, just like random channel assignment. After that, a new assignment scheme is created which is compared with the initial assignment. If interference is reduced, then it is applied, else it is rejected. This runs until the algorithm finds no further improvements. [2] [10]

T. Genetic Algorithm

Genetic Algorithms (GA) are basically those which uses the natural process of evolution which involves that only fit solutions are used and rest are discarded. It defines its population in a structure which is similar to chromosomes. They are assigned a fitness value calculated by a fitness function. The population with high fitness value is selected and given as initial population. On this, the process of crossover and mutation are applied. Crossover points are selected and the parent set selected from selection procedure is used to make offspring by swapping the values in the crossover point. Mutation occurs on the basis of probability defined by the user and it is randomly distributed to the population. If it is high, then mutation occurs so that diversity in the sample space is ensured. After this a new sample solution set is created. This process runs for a number of generations and runs. The fitter solutions stay while others are discarded. The higher the fitness of the solution, the greater is the chance of it to survive. This process is explained in the figure below: [1] [12] [18] [19] [20] [21]

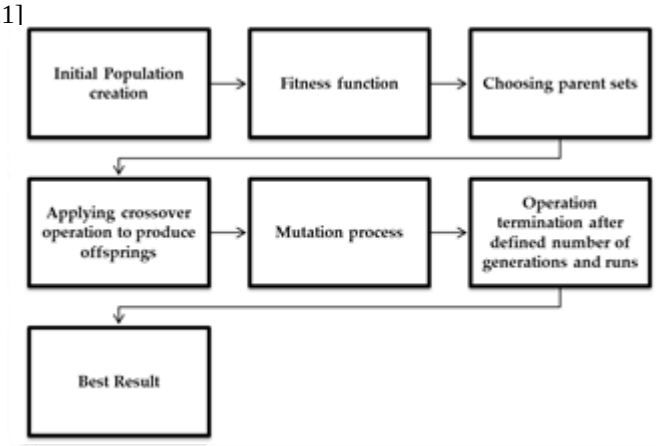

Figure 2: *Genetic Algorithm Process*

U. Use of Genetic Algorithms to solve the channel Assignment Problem

According to the article [1], the most important problem for multi-radio and multichannel Wireless mesh network is for channel assignment (CA) and multi-channel routing (MCR). Both of them when combined makes NP-hard problem. They have applied genetic algorithm to solve to CA problem and for MCR, linear programming was chosen. However, as they both are related, therefore a fitness value for chromosome in genetic algorithm is defined to separate them. Three network architectures were chosen to perform this task. It targeted infrastructure mesh network. Orthogonal channels are supported in this network. The three types of WMN are:

- Type I: The radios at each of the wireless mesh router are greater or equal to other devices (upper bound). This is because the devices of users are to be used and each has different computational parameters, therefore the number of nodes allowed at each node is restricted.
- Type II: All the mesh routers' radio interfaces (total radio interfaces in network) are upper bounded. It is assumed that all the routers have equal capabilities and performance.
- Type III: Same as type II. The only difference is that the location of gateway is unknown.

Throughput and routing optimization was carried out by Linear Programming. Some of the assumptions are:

- All traffic is from the internet and upper limit and lower limit of uplink and downlink load are predefined.
- Channel probing measurement used for data rate definition.
- Symmetric and Asymmetric gateway capacities for downlink and uplink offered.

- Radio connectivity can be shown and for some cases, if two devices have radios running on same channel, then they can be connected.
- Interference range is within two hops of all links. [1]

Throughput is maximized by introducing simultaneous flow of traffic using the orthogonal channels. This linear programming can split the traffic load for better behaviour.

As mentioned earlier, for channel assignment genetic algorithm was used. This algorithm takes inspiration from the natural way of evolution where the more stronger and fit individuals live. It involves the process of selection of good solution (made in forms of strings like chromosomes) using fitness function, carrying out crossover operation to create offspring and then perform mutation. This is a recursive process which runs for a certain defined number of generations and runs. After the selection of initial population, roulette wheel selection procedure is used to make a population set. For crossover, each subset in population has a probability defined that determines which has more chances for selection. On selected parent sets, crossover operation is performed, which refers to swapping or shuffling. In this case, two point crossovers were used where the selected points are swapped. After this, mutation assigns a small probability to the new set which refers to the probability of change after crossover procedure. All this procedure runs for defined time after which the result set is given. Mutation is used so that the set is not restricted to local solutions. If a gene's probability is higher, then it is mutated. In this, it is substituted with other substring. After this, a whole new population is made and time is incremented. The calculation of fitness here is through linear programming. If any set is unfit, then it is not used. [1]

If there is constraint like in type II and III which restricts the number of radios at each node, then an additional check would be needed to ensure this restriction is followed.

In type III, as gateways are not to be predetermined, thus gateway strings are defined to denote the routers acting as gateway. A check for duplication is also made.

This was tested against Decremental interface management (DIM: all radios are tested and those that are not useful are removed), hyacinth (makes multiple spanning trees and favors the shortest path to gateway and uses the least used channel for communication) and Particle swarm optimization (PSO: iterative process which uses conflict graphs, chooses population, performs fitness function and crossover but not mutation).

The genetic algorithm methods proposed in this paper perform two to three times better than other methods compared. Hyacinth performed the least as trees involve routing in single paths. PSO performed somewhat better than hyacinth, but it does not consider the traffic demands and equal treatment was given to each router. DIM was much better than the two as it did cater different demands of traffic, however removal of radios one by one was given solution in local space. Thus it was not better than Genetic Algorithm. [1]

The research paper [19] also compared the performance of genetic algorithms with other algorithms like random, greedy and tabu. The result was that genetic algorithm performed better and the interference decreased as the number of radios per node increased. [20] also concluded that genetic algorithm was 15% to 20% better in terms of performance than greedy algorithm. SDP algorithm gave better results than genetic, as mentioned in [19], however to achieve best results using SDP requires more computation power than genetic.

The focus of this research was to identify if genetic algorithm can be as good for an ad hoc based network too as the infrastructure of these were access point or router based. From literature survey, it can be concluded that as genetic algorithm has outperformed other channel assignment algorithms for an access point based network, therefore the chances for it to perform better than other algorithms in ad hoc based infrastructure are also high.

IV. Research Methodology and Experimental Details

This research was a mixture of exploratory, comparative and experimental methods. It involved exploring publications and research papers from authentic resources like IEEE and ACM. From this, the initial information was acquired along with the current methods of channel assignment. Matlab was studied and how genetic algorithm can be applied to solve this problem. Finally a comparison of the results was made.

A. Research Flow

The research involved several stages. It was initiated with an idea and to support that literature search was carried out. After that, detailed and in-depth study about the domain was done along with MATLAB and genetic algorithm was studied. All the stages of genetic algorithm were described and how they will be implemented. Finally, all the findings were put in this report.

B. Genetic Algorithm

1) **Population.** The genetic algorithm needs to be given a population set which in this case are the random graphs. These are then converted into conflict graphs using a function. The way the random graphs were converted to conflict graphs is mentioned in the next section. As [19] also states, these graphs first need to be converted into a form which can be given as input to genetic algorithm. One way to represent this is by making genes represent the state of a channel and the whole chromosome as a node. Each bit denotes the state of a channel. For example, 12 channels refer to 12 genes (or bits). These 12 genes will form a chromosome. If the node occupies channels 1, 4, 6 and 8 then those bits will be on and rest will be off. The number of chromosomes would be equal to the number of nodes.

2) **Fitness Function.** This is the most important part of the genetic algorithm. The fitness function basically needs to meet the number of radios and number of channels criteria. However, the most important part is for a solution to be fit is the need

for lesser conflicts. The lesser the number of edges in conflict graph, the more fit a solution is. In this case, 12 channels are considered because 802.11a is selected. These channels are orthogonal or non-overlapping. The number of radios is same at each node. Therefore, the channel assignment needs to be done in a way which can help reduce the conflicts and decrease the number of edges in conflict graph. Moreover, it needs to maintain connectivity with its neighbors. The fitness function would give the best possible results which could be used for reproduction. The chance of being selected for reproduction is actually based on the score from this fitness function. For reproduction, it is possible for a chromosome to be selected for more than one time. Along with that, it is also possible for some chromosomes to not get selected at all. To reproduce, two random pairs are selected as parent sets.

3) **Crossover and Mutation.** Parent sets are to be randomly selected on which crossover operation needs to applied and mutations is needed to give genetic diversity and not get stuck in local optima.
4) Crossover operations help in giving better solutions. These create new sample points for making different generations. Two point crossover is a common technique for crossover and also used in various other researches like [1] and [19].

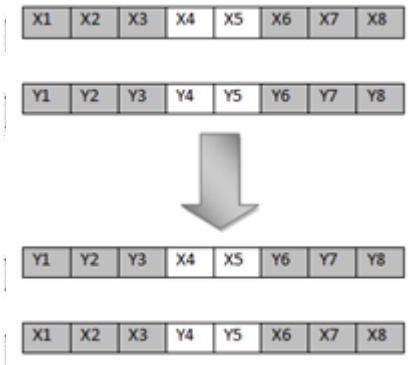

Figure 3: *Two point Crossover*

5) Mutation operator is applied on chromosomes on random basis. A probability is given which determines whether it will be mutated or not. This helps expand the search space and give more options to become solutions. It involves changing a value (gene) in a chromosome. The change can have different affects and if they get high fitness scores then they are kept. Flip bits is a common practice for mutation. If a gene's probability is high, then it is mutated. In this case, the bit will be reversed, which means if it was 0 then it will become 1.
6) For the entire population, fitness values are calculated and only the best of the solutions will survive.

C. Conflict Graph

Conflict graph was prepared with a function. When a graph g was passed to it, a conflict graph was created. It is known that if two edges interfere with each other, then this will lead to an edge being formed in the conflict graph. A vertex in a conflict graph represents a link. If there is an edge in a conflict graph then it is because the edges are interfering in the random graph. [2] [3] Due to this, the aim is to reduce the number of edges in the conflict graph. Following figures taken from [2] shows the concept of conflict graph. If same channel is used by multiple links with a certain interference range, then it is not allowed and a link is made for all those in conflict graph.

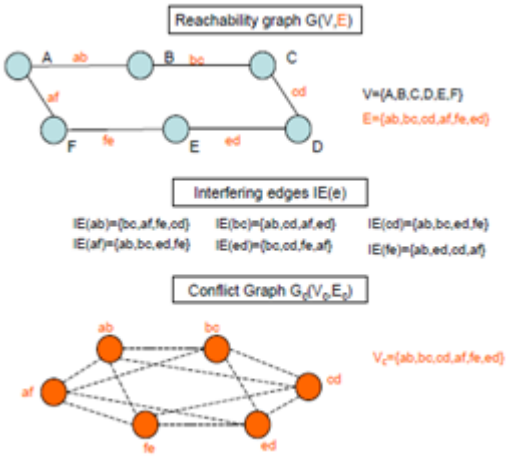

Figure 4: *Conflict Graph Concept [2]*

The interference model can now be visualized from this conflict graph. Using same channels would mean there is interference. Therefore, giving different channels could lead to reduction of interference and edges in conflict graph. As number of channels is just 12, and in real world scenario, it is very difficult for each link to run on a different channel, therefore interference is always targeted to be minimized and is difficult to be entirely eliminated.

Following is an example of a random graph with 10 nodes. The area is 500 square meters and radio range is taken as 150. This graph has 10 vertices with 12 edges.

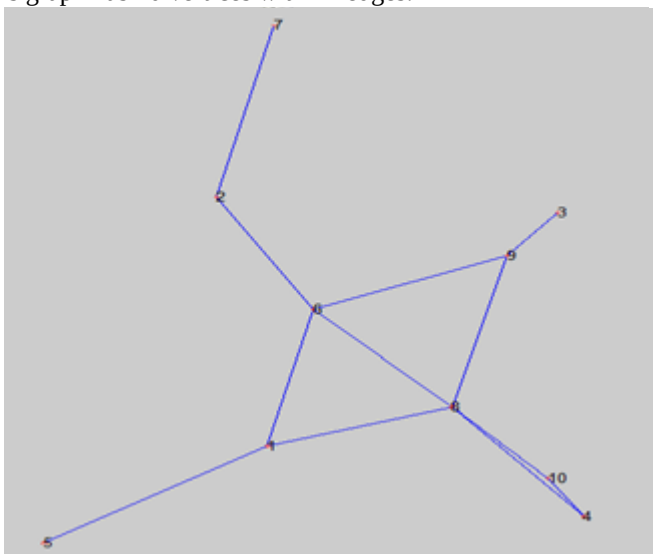

Figure 5: *Random Graph, g, with 10 nodes, area of 500 square meters and radio range of 150 meters*

As there are 12 edges in this random graph, then there will be 12 nodes in the conflict graph. Each of the nodes will be representing an edge from the random graph. This function makes use of another function to find out interfering edges. Following is the conflict graph for the above random graph.

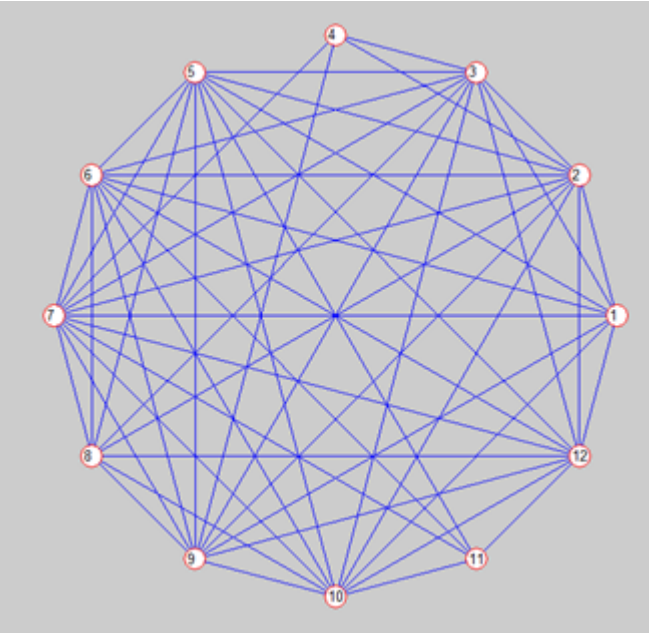

Figure 5: *Conflict graph of g with 12 edges and 53 edges*

The nodes represent the edges in random graph, as mentioned above. Following are the representations:

- Node 1: 1<-->5
- Node 2: 1<-->6
- Node 3: 2<-->6
- Node 4: 2<-->7
- Node 5: 1<-->8
- Node 6: 4<-->8
- Node 7: 6<-->8
- Node 8: 3<-->9
- Node 9: 6<-->9
- Node 10: 8<-->9
- Node 11: 4<-->10
- Node 12: 8<-->10

V. Analysis And Findings

From the study, it was clear that genetic algorithm has a lot of potential to give optimal solutions to the channel assignment problem. Through literature, it was observed that it worked better than various other algorithms such as greedy and tabu in terms of interference and giving maximum throughput for access point based infrastructure.

For this research an in-depth study on genetic algorithm and how it can be applied using MATLAB was done. All the procedures of genetic algorithm which begins with initial population, fitness function, selection, crossover and mutation were explained along with how it can all be applied altogether in order to solve the channel assignment problem.

The input to genetic algorithm is basically the conflict graph and the aim is to minimize the edges in it in order to reduce to interference which would mean increase in throughput. This input required a function to create it. Details about it were mentioned above. Moreover, using random graphs, the conflict graphs are created.

As a good amount of time was spent in problem understanding, learning about genetic algorithm and MATLAB, etc. so genetic algorithm could not be implemented fully and simulations could not be made. However, a roadmap is provided with all the details of how it can be implemented in order to give good results and this will be implemented in the next part of this research along with covering various other aspects mentioned in the future work section of this report.

VI. Limitations

The limitation of this research included the researcher's knowledge and experience on working on MATLAB and genetic algorithm. A large amount of time was spent in learning them and formulation of problem and roadmap of how the problem could be solved using genetic algorithm. Due to this and time constraints, the genetic algorithm simulations could not be made and this work is now added to future work.

VII. Conclusion

Channel assignment in wireless mesh networks with multi-radio, as mentioned in the earlier sections too, is an NP-Hard problem. This research studied about how this problem for an ad hoc based infrastructure can be solved using genetic algorithm. Various other algorithms can also be used which includes random, greedy, Tabu, etc. However, not all of them can give the best possible channel assignment solution which not only minimizes interference and maximizes throughput. Along with that, it should also meet the radio and channel constraints and ensure connectivity with the neighbors.

This paper worked on this problem to provide how genetic algorithm can be applied by giving a roadmap and explaining what needs to be done at each stage to ensure the proper application of it. Moreover, conflict graphs are also prepared so that, they can be given as inputs to the genetic algorithm. However, due to time constraints, full implementation could not be achieved. The implementation phase is added to the future work along with other things.

From the literature studied, it was identified that genetic algorithm proves to be a good choice for solving channel assignment problems for access point based wireless mesh networks. It worked better than many other algorithms like random, greedy and Tabu. From this, it can be concluded that it can also give better results for ad hoc infrastructure too, thus proving the hypothesis. However, in future, implementation and comparison with other algorithms can tell by how much percent it can perform better than others.

VIII. Future Work

As mentioned earlier in the report, due to some limitations and time constraints, the genetic algorithm could not be completely implemented. Therefore, future work involves applying genetic algorithm to this problem as defined in the

paper, making simulations and comparing the results with other algorithms. Moreover, enhancements to genetic algorithm could also be made for better results, Apart from that, use of partially overlapped channels could be put in use to increase the number of channels that could be assigned. Finally, comparison in terms of cost in terms of processing power vs. the throughput maximized or interference minimized could also be done in order to give a complete picture to show the practicality of each algorithm.

Acknowledgment

I want to thank Allah for helping me overcome all the difficulties and guiding blessing always. Then I want to thank my parents for their support.

Also I want to thank Dr. Husnain Mansoor Ali, MS Computing Coordinator and my Independent Study Supervisor, for all his help, guidance and teaching me how a good research can be done.

I would also like to thank some other people who helped me learn MATLAB and other aspects which helped me in completing my research. They include; Mr. Wajeeh Ul Hasan and Ms. Salma Tajuddin. Finally, I would also want to thank all my friends, teachers and all the other who supported and helped me in this journey.

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