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A Survey on Channel Assignment Techniques of Multi-Radio Multi-channel Wireless Mesh Network

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Abstract

Wireless Mesh Network is a promising network standard as it provides reasonable and inexpensive solutions for various types of applications. In the recent times, it has gradually developedin the direction of Multi-Radio Multi-Channel Wireless Mesh Network(MRMC WMN) architecture, which improves performance of network by providing multiple radio interfaces to every node in the network and by equipping several non-overlapping channels. In this paper, research work of variousauthors has been analyzed and found that various authors proposed modified channel assignment techniques to improve the network performance.Lot of different methods and techniques are used by them to reduce the co-channel interference. It is found that very few authors measured the traffic flow in network for channel assignment. It is asalient area and it must be carefully examined during the channel assignment. In this study, it is observed that traffic flow along with power control and topology control must be considered for efficientchannel assignment.Channel assignment is essential to make sure the best possible utilization of a few numbers of channels in the frequency spectrum.Efficient utilization of MRMC WMN can be obtained by intelligent and dynamic channel assignment.

Keywords: Channel Assignment, Interference, Multi-Channel, Multi-Radio, Radio Interface, Wireless Mesh Networks

1. Introduction

Wireless Mesh Network is an encouraging key area, supporting various types of emerging and corporate applications e.g. network neighbourhood, broadband home networking and disaster management[1]. Due to its characteristics of being flexible, trustworthy and cost effective, it is providing broadband network access over wide areas through multi-hop communication. This technology is equipped with most promising concept, for auto configurable and self-organizing wireless network with multi-hop and mesh technology[2].

The general architecture of Wireless Mesh Network (WMN) is divided into three unique elements: mesh gateway, mesh routers and mesh clients as shown in Figure 1. Mesh routers communicate with neighbour nodes in a multi hop manner in a way such that packets are simultaneously transmitted over multiple wireless links.

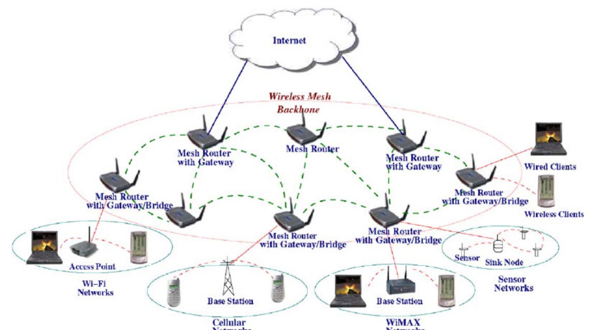

Figure 1. Architecture of WMN.

Mesh routers, connected to the wired backbone are known as gateway nodes that transfer traffic inside and outside of the mesh network and contain advanced routing functionalities to support mesh networking. Mesh clients are associated with Mesh router to use the services in the network[3]. WMN can be categorised into

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three parts such as Single Radio Single Channel (SRSC), Single Radio Multi Channel (SRMC), and Multi Radio Multi Channel (MRMC) wireless mesh networks[4]. SRSC WMN ensures network connectivity because all nodes are aligned on the same wireless channel. All nodes compete to access the same channel. Parallel transmissions can be achieved by SRMC WMN by assigning radios belonging to different nodes with different Orthogonal Channels (OC), which ensures improved network capacity. In MRMC-WMN, it is possible to use more than one network interfaces operating on separate radio channels. Mesh router consists of multiple Network Interface Cards (NIC) and every NIC is aligned with different frequency channel (separate on each NIC) thus making multiple transmissions occur concurrently[5]. This allows a potentially huge enhancement in the capacity of the WMN. A number of interesting research studies have been carried out on multi-radio networks which have concluded that multiple radios can significantly enhance the throughput and network performance.

WMN operates on two sets of standards in 2.4 GHz and 5 GHz Industrial, Scientific and Medical (ISM) band. The 802.11b standard works in the frequency range of 2.400GHz to 2.4835GHz. It is divided into 11 overlapping channels, each 30MHz wide. As shown in Figure 2 merely three orthogonal or non-overlapping channels 1, 6 and 11 allows interference free communication in a network. The IEEE 802.11a was introduced to provide a higher throughput of up to 54 Mbps, by using 13 non interfering channels operating in the 5 GHz frequency band. The 802.11g standard was introduced to improve the data rate limitation of 802.11b, which provides highest data transfer speed upto 54 Mbps on 2.4 GHz ISM Band[4].

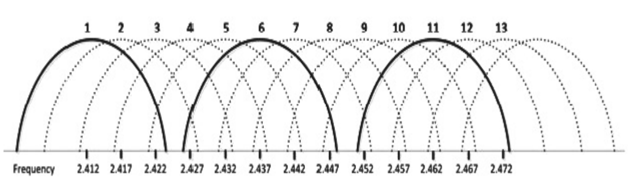

Figure 2. IEEE 802.11b/g orthogonal channels.

The multi-hop architecture of WMN and the fast growth of network throughput demand leads towards MRMC solution in mesh networks. But the co-channel interference, being the major issue, decreases the overall network throughput, particularly in multi-hop networks.

2. Channel Assignment

Channel assignment is a powerful management tool which can be used to take the advantage of the available resources efficiently. It is a network-wide process and can lead to significant improvement in throughput and media access performance of the network. Efficient utilization of MRMC WMN can be obtained through intelligent channel assignment. The process which ensures that all the nodes within the communication range are assigned with orthogonal channels or partially orthogonal channels is identified as the Channel Assignmentprocess.

In[5]authors found that equipping the MRMC architecture in WMN can improve the network performance. It states that the network functions, i.e. channel assignment, topology control, power control, and routing are encapsulated to each other. Topology control can be considered a management function block with respect to the protocol layer of MRMC WMN. In this paper authors studied many methodologies which were demonstrated with combined features of topology control, channel assignment,power control, and routing. In[6]authors proposed a Demand Based State Aware Channel Reconfiguration Algorithm to reconfigure the assigned channels.Algorithm is broadly classified in to three major steps namely flow allocation, channel assignment, and link scheduling. This algorithm tries to reduce the reconfiguration overhead of CA by examining the traffic load variation in the network. In respect of variation in the traffic load in network, the channel has to be reallocated to attain maximum throughput in the network. This algorithm evaluates the channel reallocation policy based on maximizing network utilization and minimizing traffic disruption.

In[7] authors proposed channel assignment approach based on path forwarding weight factor, contention window size, distance, and receiver mobility. For better utilization of all available channels, they assign channels by using the channel separation and the distance between nodes. To improve the overall network throughput,theyarranged the channel sequence among all the nodes based on path forwarding weights in the decreasing order. Results shows that the approach proposed by authorsachieves better than the one proposed by Zeng and Nguyen in terms of co-channel interference, network throughput, packets delay and virtual transmission time.

In[8] authors came up with a Centralized Rank Based

Channel Assignment scheme, which calculates the rank based on weighted cumulative expected time to and from gateway, numbers of NIC per node, and aggregate traffic. Aggregate traffic streaming has considerable impact on the channel assignment algorithm. The first channel is assigned to the node which attains higher rank. This scheme improves the network efficiency in term of overall throughput and increases the channel utilization to a large extent. Mixed Integer Linear Program proposed in[9] to formulate joint channel assignment and flow control oriented problem for MRMC WMNs. It illustrates that to provide better performance from multi-channel networks the non-overlapped channels can be effectively replaced by the partially overlapped channels. Simulation incorporates the transmission strength of every node, traffic load, path loss information and noise ratio at each node. It makes maximum utilization of the spread spectrum, by implementing better channel and flow allocations technique, without the use of any additional spectrum. Static Channel Assignment Model proposed in[10] to solve the issue of channel assignment in MRMC WMN, tries to minimize the co-channel interfaces and to increase the link capacity of the mesh networks. Accuracy of channel assignment is determined by using the described interference model. Simulation results shows more practical and realistic improvements achieved by taking into account the connectivity and radio restriction under the interference model.Authors described in[11]that to improve the link capacity and the overall performance of WMN, nodes should be designed with more than one network interfaces and mapped on multiple non-interfering channels. They proposed channel assignment algorithm based on Link priority, Traffic load and Interference awareness. It defines priority to different links and then assigns channels according to high priority first. Priority of link is evaluated based on distance from Mesh point portal and traffic load is evaluated according to amount of data forwarded to neighbour node. Proposed algorithm improves the network throughput significantly. Authors in[12]used the Latin square for channel assignment. Based on Latin square, they introduced competent channel assignment, scheduling and routing protocols for MRMC WMN. They organized the network into clusters and ensured the node to node connectivity using interference cluster and bridge cluster. Channel assesses effectiveness and fairness is obtained by applying compact Latin square. Simulation result shows that proposed algorithms attains a large amount of better performance as compare to IEEE 802.11 standards and other channel assignment algorithms.

In[13] authors found that due to lossy and highly unpredictable wireless channels the performance evaluated by routing protocols in WMN is quite poor. By using opportunistic throughput gain and multi-channel throughput gain they proposed Workload Aware Channel Assignment and Routing algorithm.This algorithm allows any node to overhear the packets over multiple hops for forwarding the data packets. The aim of this algorithm is to improve the network efficiency and network throughput.In[14] it is stated that in case of multi hop networks, where only one network interface node is being used, the throughput decreases due to the higher number of hops between end to end communications. They proposed Connected Low Interference Channel Assignment with automatic channel allocation approach to improve the network throughput and to decrease the interference. By sharing channel allocation information, proposed algorithm allocatesthe different frequencies and the non-overlapping channels to improve the network efficiency and minimizes co-channel interference.In[15] authors proposed Flow Oriented Graph Coloring and Flow Oriented Channel Assignment algorithms to improve the channel assignment technique and network throughput. These algorithms identify bottleneck in network at each iteration using network information like routing paths and topology structure and try to avoid the network congestion by switching the channels, optimally controlling the data rate and assigning new channel. These algorithms ensure the conflict free and interference aware channel assignment. Results of Flow Oriented Channel Assignment algorithm are compared with Load Aware Channel Assignment algorithm in respect of point to point network throughput and per flow throughput.Authors in[16] proposed a Topology Controlled Interference Aware Channel Allocation algorithm for MRMC WMN using the minimum spanning tree. Algorithm allocates channels to multiple interfaces of nodes by using network topology control information and power control information. After controlling the power of each node, shorter links are deployed to control the interference. Proposed algorithm ensures that overall network throughput is maximized, interference in network is minimized, and overall network connectivity is maintained.Authors shows in[17] that insufficient availability of radio channels and numbers of network interfaces per node restricts the required bandwidth on wireless networks and ultimately reduces the attainable throughput. They proposed a Utility Based Channel Allocation algorithm which allocates channels to links depends on their utilities. By judging the link utility makes it very simpler to evaluate the usefulness of the link. Effectiveness of proposed algorithm has been evaluated and it has been found that it achieved significant increase in network capacity and considerable decrease in co-channel interference. In[18] authors determine that the appropriate number of orthogonal channels needs to attain interference less data transmission in MRMC WMN.It analyze the impact of three different models i.e. protocol model, signal-to-interference ratio (SIR) model, and SIR with shadowing model on channel assignment. They proposed an effective and less complex way to construct conflict free graph based on SIR with shadowing and to find appropriate channel for each node on conflict free graph. SIR with shadowing is an improved physical model which can analyse the shadowing effect on each link.

In[19] authors stated that Multi radio mesh nodes configured on multiple non-overlapping channels can bring higher network performance. They successfully worked on aDistributed Interference Aware Channel Assignment algorithm considering an external interference for MRMC WMN. If any channel overloaded due to high amount of traffic the proposed algorithm finds the least used channel within the communication range and assigns channel dynamically. Results demonstrate that proposed algorithm improves the network throughput significantly as compare to the Centralized Channel assignment algorithm. By analyzing the real network data authors proposed Traffic-Aware Channel Assignment algorithm in[20]. In addition to this they also projected a Centralized Greedy Channel Assignment algorithm that re-assign channels based on two parameters i.e. low computation complexity and previous channel assignment information. Results are compared with Flow Aware Channel Assignment and a static channel allocation that set up edge priority by calculating the distance to the gateway. It shows up to 72% improvement in datatransmission rate of TCP flows and 59% in median rate. Authors in[21] defined the optimization problem of utilizing the multiple radios with multiple channels in MRMC WMNs. They proposed Link Centric and Traffic Independent Channel Assignment algorithm to achieve required link performance while minimizing the co-channel interference. They used a Greedy Channel Assignment technique that approximates both upper level and lower level of interference. This helps to decide the channel to be allocated to link and to predict the maximum and minimum network performance.In[22] authors describe that if two links are operating on identical channel and they are in the communication span of each other, then they generate co-channel interference and decrease link capacity. They come up with an improved version of Topology Controlled Interference Aware Channel Assignment algorithm to enhance the network efficiency and fairness ratio. It calculates the rank based on connectivity graph and shortest path tree and assign channel to higher rank first. As per the study the algorithm is found to be a better channel assignment algorithm. Because it recognizes all least interfering channels and it does not assign the identical channel which are in the communication span of each other in the network.

Authors in[23] proposed an Auction Based Channel Allocation algorithm, using optimal coding sub-graphs for all connections. Proposed algorithm finds an optimal channel assignment for all nodes. In this article authors evaluated the mutual issues of channel allocation and connection scheduling for an MRMC WMN. Simulation results show that unfairness raised from the auction can be controlled by appropriately managing the packets size and assigning more numbers of channels. In[24] authors,based on real traffic flow,proposed a channelallocationalgorithm for MRMC WMN. Traffic flow is an important factor which should be measure during the channel assignment. They proposed to equally distribute the traffic between nodes so that the traffic distribution among all nodes is equal. This algorithm ensures the network connectivity among various nodes, uniform distribution of traffic and minimum interference valve in network. This disappear the effect of overall interference from network and make it much more reliable. Authors in[25] identified the hidden node problem and interference among various links and proposed the channel assignment algorithm for MRMC WMN. Due to hidden terminal problem and interference in wireless network, condition of collision, transmission delay as well as packet losses have occurred. Proposed algorithm reduces the hidden terminal problem and increases the carrier sensing. Simulation result shows that projected algorithm outperforms in terms of network throughput as compare to the previous algorithms.

Loop Based Dynamic Distributed Channel Assignment algorithmformulated in[26]. Authors used grid-loops and group channels which provides a novel algorithm for channel assignment in MRMC WMN. Results are compared with existing Cluster Based Channel Assignment and found that proposed algorithm is much more balanced, cost effective and efficient. Because this algorithm has efficient clustering mechanism and simple robust structure. Hybrid Channel Assignment and Routing Protocol Proposed in[27] to minimize co-channel interference. This algorithm makes use of load balancing in route and finds a route which satisfies the quality of service requirements of the incoming network traffic. Test-bed experiment demonstrates that interference is reduced significantly and network throughput is improved considerably. Also it has the ability to avoid congestion causes in the network and improve the network utilization. It also enhances the QoS support for bandwidth intensive traffic.Authors in[28] suggested a Dynamic Channel Assignment algorithm that intelligently re-allocates channels to links so that the re-routing overhead/latency can be reduced during nodes handoff. The proposed algorithm achieves enhanced load balancing between mesh routers by re-assigning the channels. Enhanced channel re-assignment increases the capacity of MRMC WMN and supports more users while satisfying their QoS requirements. Experimental resultsshow that proposed algorithm performs better in terms of packet delay, packet loss rate and network throughput. In[29] authors have claimed in their study that due to shortage of orthogonal channels and more numbers of network interfaces per node, co-channel interference exists, that reduce overall network throughput. Level of interference in network can measured from closeness of allocated channels to the radio interfaces.They proposed Maxflow Based Centralized Channel Assignment strategy to increase network throughput and reduce the co-interference problems. Effectiveness of proposed algorithm has been evaluated and found that it performs better than previous strategy and leads to better network performance.In[30] authors advocated a hybrid MRMC WMN architecture, in which every node has one static radio interface and one dynamic radio interface. They developed an Adaptive Dynamic Channel Assignment algorithm, which took care of optimization of channel assignment in available links. They also proposed an Interference Aware and Congestion Aware Routing Protocol. This protocol maintains the balance of channel usage in network. Simulation results describes that Adaptive Dynamic Channel Assignment algorithm reduces the end to end delay without affecting the overall network performance.Authors also said that by adopting the hybrid approach in network is much suitable for real time traffic as compare to static approach.Authors in[31] proposed channel assignment algorithm to minimize issues related to channel switching and to maximise network throughput. During channel switching, network performance can be affected from switching overhead like switching delay and synchronization drift. They proposed to divide the mesh points in two parts. In first part channels are assigned permanently and stay tuned on the same channels. In second part dynamic channels are assigned to links as per requirements. By using the second part various channel switching issues can be eliminated e.g. switching delay, synchronization drift, etc. Experimental outcomes describe that the proposed algorithm outperforms in terms of packet drop rate and network throughput.In[32] authors introduced an Integer Line Programming Distributed algorithm to come across the solution of channel allocation problem which may leads due to improper network partition and link failure. Authors concentrate on the various issues of channel assignment with original topology preservation and try to reduce the network interference. Proposed algorithm performed better in both crowded and sparse networks in terms of network throughput and co-channel interference in comparison to the previous studies. Authors in[33] hold the view that due to the large scale traffic in WMN, fault tolerance and scalability has become an imperative issue. To present fault tolerance and automatic fast failure recovery they proposed a Topology-Controlled Interference Aware Channel Assignment (TICA)algorithm and failure recovery mechanism. Simulation has performed on random, controlled random and grid topologies and it was found that the proposed algorithm outperformed as compared to CCA and SRSC in terms of scalability and itgives best performance in networks with large number of nodes. In[34]authors proposed a channel assignment algorithm based on three parameters i.e. traffic flow, transmission power and data rate allocation. This algorithm analyzed the effect of controlling the transmission power,data rate on a channel, and the competence of channel assignment. Authors try to improve the channel assignment efficiency by controlling the transmission power and data transfer rate of the wireless links. Proposed algorithm outperforms as compareto the previous algorithms in term of flow rate. Centralized and Distributed Algorithm proposed in[35] to reduce the network interference. After simulation in NS-2 simulator effectiveness of proposed algorithm has been evaluated and it was found that it performed better in terms of network throughput than the previous algorithms. In[2]authorsexamine various channel assignment algorithms using network interference, traffic pattern, and connectivity of links and compare to each other. They also proposed Mesh Based Traffic and Interference Aware Channel Assignment algorithm by using ranking function. This algorithm considers the network traffic on link, hop count from gateway node, and number of radio interfaces per node. Rank of link is calculated by examine the properties of traffic, network topologyinformation and number of radio interfaces per node. In[36] authors concentrated on high speed Multi-hop Wireless Mesh Networks where high speed data transmission is required. Due to congestion in network overall performance is degraded. Authors proposed an Enhanced Congestion Control mechanism for wireless mesh networks. This mechanism measures the available bandwidth and tries to reduce the congestion in network. Simulation experiment has been performed in NS-2 Simulator and found that it performs better as compare to existing mechanisms. In[37] authors said that when number of hops increased in wireless mesh network then performance of network starts decreasing. Authors introduced an Angle Based Multicast Routing Algorithm which reduced the number of hops and communication overhead in network. Proposed algorithm calculates the angle of each node. If the angle is less than 60^{o}then every intermediate node is selected for further communication. As compare to CAMP AMRA proposed algorithm perform better in terms of overall network performance. In[38] authors describes that in wireless mesh networks routing is the key area where major problems have occurred. Field Based Routing Algorithm uses very less route information to find a path. But this algorithm is less secure and faces various security issues. In this research work authors proposed aNovel Enhance Secure Field Based Routing Algorithm to extend the Field based routing algorithm and to solve the security related problems. Proposedalgorithm identifies and isolates the malicious node and prevents the data from various attacks.Authors In[39] said that presence of multiple loops in Wireless Mesh Networks degrades the network efficiency and makes the network management more difficult. Authors introduced the autonomous link recovery system which, automatically recall network channels and radios. Autonomous link recovery system is implemented in NS-2 simulator and found that it improves the 90% network efficiency.

4. Conclusion

The Multi-Radios Multi-ChannelWireless Mesh Network (MRMC WMN) is one of the most admirable concept to network scaling. Channel assignment is an important research issue in such MRMC WMN. This is a network-wide process where the allocation of non-interfering channels leads to significant throughput increase and better media access performance. In spite of the availability of more than one channel, only some channels are non-overlapping and while others are partially overlapped. Because only ahandful number of channels are available, Co-channel interference exists between various radio signals which are running on the same frequency channel. Co-channel interference can severely affect the performance of WMN resulting in capacity reduction of the channel. In this paper, significant attempt has been made to provide an insight into the futuristic approaches proposed for channel assignment in MRMC WMN research area by the various authors.

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