Parameter Based Taxonomy for Channel Allocation in MRMC WMN

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Abstract—Wireless Mesh Networks are emerging trend in Wireless Networks for their low cost, easy access, self healing and self organizing capabilities. Despite the fact that WMNs work efficiently, they are heavily impacted by interference in the channel. To overcome this problem several researches suggest Multiple Radios and Multiple Channels (MRMC) in WMN. MRMC networks improve the overall capacity and throughput of the network. The MRMC WMN includes many issues like Channel Allocation (CA), scheduling and routing. Lot of research work is done and is going on to solve the issues of CA in MRMC WMNs. The authors of this article aim to propose the taxonomy of different CA algorithms based on key performance parameters namely throughput, network capacity and both. Network throughput is the rate of successful message delivery, so as throughput increases, distribution of message between the users also improves. Scalability of network enhances the network capacity to fulfill high demand of internet connection in the world. The scalability of MRMC WMN is analyzed through simulation using network simulator NS3.22. The results of the simulation shows that the selections of efficient CA scheme plays an important role to improve the network performance.

Index Terms—Graph algorithms, Multi radio and multi channel communication, Channel allocation, WMN.

I. INTRODUCTION

Wireless Mesh Network (WMN) is a reliable, multi-hop, high bandwidth and inexpensive broadband access network. It consists of mesh routers, mesh clients and gateways. Mesh routers form the backbone of the network providing communication to mesh clients among themselves and to/from the external network. Gateways provide internet access to all the nodes of WMN through wired connection. Mesh clients are laptops, mobile devices and other wireless devices that perform simple client functionalities. The capability of mesh routers to forward packets along with the basic access point tasks appeals various applications. Some of the areas where WMNs find applications in are security and surveillance systems, building automation, health and medical systems, transportation systems, community networks, city networks etc. WMNs are utilized so widely because of their various benefits such as increased reliability, low installation cost, large coverage area and automatic network connectivity. Despite the fact that WMNs are gaining popularity, there exists some issues such as stability in topology, multi channel, routing, interference etc. which need to be addressed with innovative methodologies to improve throughput and delay of the network.

One of the challenges to enhance the throughput is to cope with the interference in the network. The interference in the transmission on same frequency channels can be eliminated by utilizing multiple radios with different channels assigned to them. To utilize this environment of Multiple Radio Multiple Channel (MRMC) in WMN efficiently, the channels must be assigned, scheduled and routed effectively within network capacity while maintaining network connectivity. Although WMN provides simultaneous transmission by using multiple radios and multiple channels, interference cannot be excluded completely. The interference mainly depends on the channels assigned to nodes which is carried out by CA schemes. Hence the choice of channel assignment plays an important role in MRMC environment.

In this paper various channel assignment schemes are studied and reviewed. The authors focus on presenting the taxonomy for different CA mechanisms based on the parameters such as throughput and network capacity. In an effort to visualize the MRMC environment of WMN, the authors also concentrate on the performance analysis of this network using network simulator NS3.

The paper is organized in the following sections; section II presents literature survey on various channel assignment algorithms. Section III provides MRMC WMN architecture, its importance and classification of CA based on parameters. Section IV discusses the result analysis of MRMC implementation in NS3. Finally the authors conclude the paper in section V.

II. LITERATURE REVIEW

Channel Assignment is one of the widely explored area of WMNs. Several research have been conducted and new methodologies are proposed to improve different performance parameters of mesh networks. Some of the approaches focus on orthogonal channels and some on both orthogonal and partially overlapped channels. The literature survey conducted in this paper is related to the various channel assignment schemes recently proposed.

Since the number of orthogonal channels are few, two nodes might employ same frequency channel for data transmission. This leads to co-channel interference, elimination of which is
the main focus of the authors of [1]. They propose I-Matrix interference model that helps in selecting channels with less interference, based on POC channel assignment algorithm. The I-matrix generated consists of the interference factor for all channel combination of radios. The channel combination with least interference factor is used for assignment. The algorithm also increases the number of simultaneous transmissions and eventually upgrades the network capacity.

Sok-Hyong Kim and Young-Joo Suh [2] proposed a Rate-Based Channel Assignment (RB-CA) algorithm to alleviate performance anomaly in multi-channel multi-rate WMNs. By exploiting multiple channels, the proposed algorithm alters a low-rate single-hop path to a high-rate multi-hop path. Thus, the algorithm delivers a large volume of traffics in WMNs simultaneously from or to the Internet through multiple non-overlapping channels along with high-rate links.

The classic cluster based channel assignment scheme (CCAS) was proposed in [3]. The author exploits multiple paths between mesh router and gateway to or form clusters. The clusters formed are assigned channels to minimize co-ordinated and non coordinated interference, thereby increasing the capacity of individual links.

Vinay Kapase [4] proposed a Cluster based Channel Assignment algorithm which works in three phases. The first phase involves calculation of Euclidean distance between two wireless mesh nodes and the formation of clusters. In the second phase interface allocation and channel assignment using greedy technique is carried out. In the third phase Channel reassignment occurs considering interference from nearby nodes operating on the same channel.

The greedy technique is also utilized in the distributed channel assignment algorithm as proposed by Ko et al. in [5]. The technique minimizes channel’s local objective function depending only on local information of nodes. Every node selects a channel that minimizes the sum of interference cost within its interference range.

Yan Xia [6] proposed channel assignment based on self-organized grid-loop i.e. forming grid-loops via Minimum Spanning Tree and through group channel. Differing from classic cluster topology, the construction of grid-loop topology not only has an efficient constructing mechanism, but also has a simple and robust structure. In each grid loop every node is assigned with an identifier(ID) . The mesh node with larger ID becomes loop creator and assigns channels for self radios. Later it assigns available channels to the remaining nodes in the loop.

The algorithm proposed by aizaz and nazia [7], TICA uses topology control algorithm based on power control to assign channels to multi-radio mesh routers. It helps to minimize co-channel interference, maximize network throughput and maintain network connectivity. Topology control algorithm selects the node with minimum transmission power and which is closer to other nodes. The node closer to gateway with less transmission power is assigned the highest rank. The channels are assigned to nodes in the decreasing order of their rank.

The interference among the nodes is also affected by the direction of radio antennas. Considering this fact the authors of [8] utilize directional antennas to assign channels for multi radio WMN. The proposed mechanism involves construction of the auxiliary network graph. The number of radios on each node and the total number of available non-overlapping channels will be formulated from this graph. There are certain constraints that need to be adhered such as dual path routing should be conducted and access points should be one-to-one associated with the gateway nodes. The flow rate of each AP-GN(Access Point-Gateway Node) pair on each link determines the routers and bandwidth allocated to each AP. This method drastically improves aggregate system throughput while maintaining fair bandwidth allocations among APs.

Game theory is a mathematical tool, particularly useful, in the network engineering field to model highly complex scenarios. [9] utilizes this concept to design a systematic approach to minimize adjacent channel interference by considering partially overlapped channels in WMNs. The authors proposed the distributed channel assignment algorithm which improves the overall performance of network by enhancing throughput and channel reuse.

Previously several researchers surveyed the various channel assignment schemes identifying the issues and challenges. The authors of [10] identified key challenges and research approaches in CA for multiple radios, infrastructure, topology , graph theory and routing dependency. They also concentrate on the goals and objectives of an efficient algorithm and provide classification and comparative analysis of different schemes.

The literature survey conducted in this section helps to identify the key parameters of channel assignment algorithms that have great deal of impact on network performance. The most focused parameters are network throughput and network capacity. Hence the authors are motivated to present the taxonomy of CA schemes based on these parameters as discussed in section IV.

III. MR-MC ARCHITECTURE

Wireless mesh network as discussed in section I consists of mesh router, mesh clients and mesh gateway as nodes. Depending on the functionality of these nodes, the architecture of WMN can be classified as infrastructure/backbone, client WMN and hybrid WMN [11]. The infrastructure/backbone WMN consists of backbone network formed by mesh routers and all the traffic are routed by them. Client WMNs are peer to peer networks wherein the client nodes do not use mesh routers to communicate and perform configuration and routing. The hybrid WMN architecture employs both infrastructure and client meshing in the WMN network, thus utilizing the merits of both architectures.

Figure 1 shows the infrastructure based WMN, mesh routers and gateway, forming the backbone of the network. Clients can communicate with the help of routers in the backbone network. For the communication to occur between mesh router and client, both the nodes should have same radio technology otherwise the clients have to connect to the base station of
The routing in WMN is conducted in the MAC layer using Hybrid Wireless Mesh Protocol (HWMP) and Peer Link Management Protocol (PLM). The Peer Link Management Protocol is applied when new mesh routers enter or exit the existing WMN. The protocol avoids the collisions in the beacon frames transmitted by the mesh routers. It establishes link between peers. The path selection in the network for data transmission is carried out by HWMP. The protocol uses the radio aware routing metric Airtime Link Cost Metric(ALM) which evaluates the link quality by measuring channel access and routing overhead along with frame error rate. The protocol works in two modes depending on the stability of the network topology, proactive and reactive mode. In both the modes, nodes transmit the control packets namely, PREQ( Path Request), PREP (Path Reply) and PERR (Path Error).

In the proactive PREQ mode, the root node periodically broadcasts the PREQ packets. The mesh router receiving this PREQ packet updates itself with the information of root node and the distance between them and then forwards the packet. The router sends the gratuitous PREP packet as a response to the root node if the PREP bit is set to 0 in PREQ packet. In the proactive RANN (Root Announcement) mechanism, the root node periodically floods RANN packet into the network. The mesh router which receives the RANN packet if needs to create/refresh route to the root then it sends a unicast PREQ to the root. When the root receives this unicast PREQ, it responds with a PREP to the Mesh router.

The reactive mode is based on the AODV protocol as specified in RFC 3561 [15]. In the reactive mode, the source mesh router transmits the PREQ packet in order to find the path to the destination node. The intermediate nodes that receive the PREQ packet, update the path to the source node if the sequence number in the packet is greater than the previous one or the metric is better. If the intermediate node does not have the path to the destination it simply forwards the PREQ packet otherwise the action of the node depends on the DO(Destination Only) and RF(Reply- and -Forward) flags. If only the DO flag is set, the intermediate nodes forward the PREQ packet until it reaches the destination node. The destination node in turn replies with the PREP packet, allowing the intermediate nodes to learn the path to the destination. If both the flags are not set and the intermediate node is aware of the path to the destination node then it transmits unicast PREP packet to the source router and does not forward the PREQ packet. In the case where DO flag is unset and RF flag is set, the intermediate node sends the unicast PREP packet to the source node and sets the DO flag while forwarding the PREQ packet. This leads to subsequent intermediate nodes not sending the unicast PREP packet back to the source node.

As discussed before, network capacity could be boosted through the usage of multiple channels for nodes. In this view, the selection of Channels for assignment to nodes play a significant role. Hence various CAAs are reviewed and classified in section IV.

IV. PROPOSED WORK

Channel Assignment is one of the fundamental aspect of MRMC Wireless Mesh Network which has to be dealt
with precision and thought. In this regard, several research has been done and various CA scheme, improving different parameters of the network are proposed. These CA schemes are designed to satisfy certain objectives such as improvement in overall throughput of the network, improvement in total network capacity, minimizing the average delay in the net-work, elimination or rather minimization of interference in the network etc. The authors concentrate on two such parameters: throughput and network capacity of CA schemes based on which the CA algorithms are classified as shown in table I.

V. RESULT ANALYSIS

One of the most widely applied area of WMN is community networking. Such networks involve rapid growth in the number of users as the community scales. Hence the network should support scalability. To visualize such environment, authors focus on analyzing the behavior of MRMC WMN with the increase in number nodes. The simulation of MRMC WMN is conducted using network simulator NS3.22. The performance study is carried out with respect to throughput and delay. The underlying environment set for the simulation is as shown in table II.

The nodes are arranged in grid topology, each with two radios. The radios are assigned non-overlapping channels statically. The distance between two edge nodes is 50m. The simulation is initiated randomly at 0.1s and is conducted for 200s.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Methodology</th>
<th>Routing</th>
</tr>
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<tbody>
<tr>
<td>Throughput</td>
<td>centralized channel assignment and routing scheme based on heuristic route discovery</td>
<td>Dual path routing protocol</td>
</tr>
<tr>
<td></td>
<td>Clustered based channel assignment</td>
<td>HWMP</td>
</tr>
<tr>
<td></td>
<td>Extended centralized traffic independent algorithm and MSTCA (Minimum Spanning Tree CA)</td>
<td>ALM (Airtime Link cost Metric)</td>
</tr>
<tr>
<td></td>
<td>Loop based dynamic CA</td>
<td>ALM</td>
</tr>
<tr>
<td></td>
<td>A game theoretic distributed CAA</td>
<td>Optimized Link State Routing Protocol (OLSR)</td>
</tr>
<tr>
<td></td>
<td>Partially overlapped channel assignment algorithm</td>
<td>Optimized Link State Routing Protocol (OLSR)</td>
</tr>
<tr>
<td>Network Capacity</td>
<td>Data rate based CA</td>
<td>ALM</td>
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<td></td>
<td>Topology-controlled Interference-aware Channel assignment Algorithm</td>
<td>ODDV (On-Demand Distance Vector) routing protocol</td>
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<tr>
<td></td>
<td>CRAFT (Channel and Routing Assignment with Flow Traffic)</td>
<td>ALM</td>
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<tr>
<td></td>
<td>Optimization model and CA based on decision variables</td>
<td>ALM</td>
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<tr>
<td></td>
<td>Multi-Channel Minimal Number of transmissions Trees</td>
<td>Multicast routing metric</td>
</tr>
<tr>
<td>Throughput and Network Capacity</td>
<td>Mixed integer linear programming model</td>
<td>MR (Multi Radio)-LQSR (Link Quality Source Routing)</td>
</tr>
<tr>
<td></td>
<td>Multi objective algorithm for channel assignment</td>
<td>Multicast routing</td>
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It can be interpreted from figure 2 and figure 3 that as the number of nodes increases throughput decreases and delay increases respectively. Since the CA scheme used is static with number of channels same as that of number of radios for each node, the behavior of both the curves is simplistic. With the
Fig. 2. Number of Nodes vs Throughput

Fig. 3. Number of Nodes vs Delay

utilization of efficient CA scheme exploiting more number of channels per radio of a node, improvement in throughput and delay could be achieved.

VI. CONCLUSION

In this paper we briefly discussed the architecture and various channel assignment algorithms (CAA) of MRMC WMNs. The CA schemes are classified based on the parameters throughput and network capacity. The classification is pre-sented in the form of taxonomy. For simplicity MRMC environment of WMN is simulated using NS3.22 with static channel assignment. The performance analysis of the simulation is conducted with respect to scalability metric. The analysis shows that with the utilization of efficient CA scheme, the throughput and delay could be improved with respect to behavior of metrics presented in this paper. The paper also helps other researchers to select the CA scheme based on the parameters.

REFERENCES


