A Survey on challenges and issues designing protocols for MRMC WMNs

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ABSTRACT

Nowadays the advancement of the next-generation wireless technologies, aims to provide high data rates in excess upto 1 Gbps. Wireless Mesh Networks is a promising wireless technologyfor several emerging and commercially interesting applications such as broadband home networking, community networks, coordinated network manage-ment that provide redundant wireless connection between the sender and the receiver. In order to improve the capacity of WMNs and for supporting the traffic demands raised by emerging applications for WMNs, Multi-radio Multichannel wireless Mesh Networks are under intense research. In WMNs, as the wirless connection length increases, it can easily be found that throughput degrades rapidly due to the exposed node problem, the hidden terminal problem, and the unpredictableand high error rate in the wireless channel.

Keyword : - *WMN, WLAN, WMANs, WPANS.*

I. INTRODUCTION

Multiple access techniques are used to provide access to a large number of users within same bandwidth. Of all Wireless mesh networks (WMNs have emerged to be a new cost-effective and performance-adaptive network paradigm for the next generation wireless Internet. Targeting primarily for solving the well-known last mile problem for broadband access [1], WMNs aim to offer high-speed coverage at a significantly lower deployment and maintenance cost. WMNs use multi-hop wireless relaying over a partial mesh topology for its communication. Each node in the WMN should operate not only as a a relay, that forward the data to and from the Internet-connected central gateway on behalf of other neighboring nodes. Fig. 1 depicts a multi-hop wireless mesh network, where only the gateway node has a wired connection to the Internet and likewise other nodes access to the gateway via a multi-hop wireless communication.

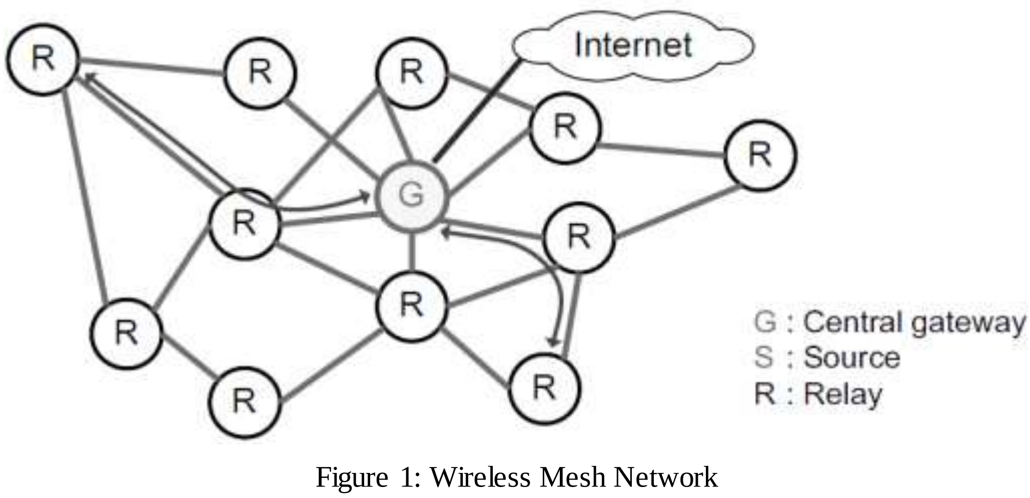

Figure 1: Wireless Mesh Network

WMNs aim to diversify the capabilities of ad hoc networks. On the one hand, ad hoc networks can actually be considered as a subset of WMNs. They share common features, such as multi-hop, wireless, dynamic topology, and dynamic membership. On the other hand, meshes may have a wireless infrastructure backbone and have less mobility. The security schemes that are in existence proposed for ad hoc networks and could be adopted for WMNs.

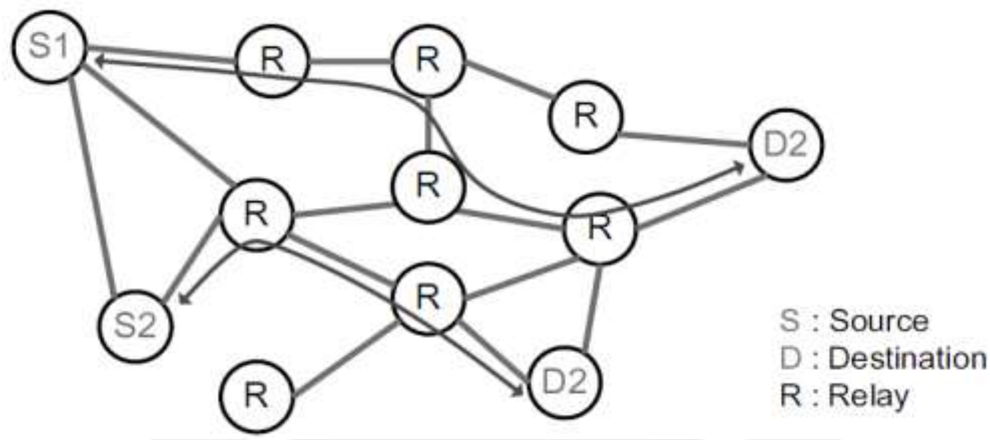

Figure 2: Wireless Ad hoc Network.

1.1. WIRELESS MESH NETWORKS

Unlike from traditional wireless networks, WMN is energetically self-organized and also, carries the auto-configuration. However, the nodes in the mesh network have automatic establishment and maintains a network connection. This aspect brings numerous advantages for the end-users such as lower costs, easy network protection, heftiness, and steadfast service coverage. In addition, the use of highly developed radio technologies like multiple radio interfaces and smart antennas, the network capacity in WMNs is enlarged significantly. Moreover, the gateway and bridge functionalities in mesh routers facilitate the integration of wireless mesh networks with a variety of operational wireless networks such as wireless sensor networks, wireless-fidelity (Wi-Fi), and WiMAX. Consequently, the end-users can take the benefit of multiple wireless networks through an integrated wireless mesh network [2-3].

Some of the benefits and characteristics of wireless mesh networks are highlighted as follows:

- **Increased Reliability**

In WMNs, the wireless mesh routers provide redundant paths between the sender and the receiver of the wireless connection. This eliminates single point failures and potential bottleneck links, resulting in significantly increased communications reliability [6].

- **Low Installation Costs**

Recently, the main effort to provide wireless connection to the end-users is through the deployment of IEEE 802.11 based Wi-Fi Access Points (APs). To assure almost full coverage in a metro scale area, it is required to deploy a large number of access points because of the limited transmission range of the APs. The drawback of this solution is highly expensive infrastructure costs, since an expensive cabled connection to the wired Internet backbone is necessary for each AP. On the other hand, constructing a wireless mesh network decreases the infrastructure costs, since the mesh network requires only a few points of connection to the wired network.

- **Large Coverage Area**

Currently, the data rates of wireless local area networks (WLANs) have been increased by utilizing spectrally efficient modulation schemes. On the other hand, multi-hop and multi-channel communications among mesh routers and long transmission range of WiMAX towers deployed in WMNs can enable long distance communication without any significant performance degradation.

- **Automatic Network Connectivity**

Wireless mesh networks are dynamically self-organized and self-configured. In other words, the mesh clients and routers automatically establish and maintain network connectivity, which enables seamless multi-hop interconnection service.

1.2. DESIGN ISSUES FOR WMNS

There are still open research issues that should be addressed in order to build high-performance and robust WMNs.

Here, we outline some of these design challenges:

- **Topology Control Under the Physical SINR Model**

Most of the studies on topology control are inherently based on the graph model that characterizes graph-theoretic properties of wireless networks, while ignoring important physical aspects of communications. Moscibroda et.al studied the problem of topology control under an information theoretic SINR model [11]. They derived the time complexity of a scheduling algorithm that assigns transmit power levels to all the nodes and schedules all links of an arbitrary network topology. They proved that if the signals are transmitted with correctly assigned transmission power levels, the number of time slots required to successfully schedule all links is proportional to the squared logarithm of the network size. They also devised a centralized algorithm for approaching the theoretical upper bound. In spite of its theoretical importance, the centralized scheduling algorithm cannot, however, be practically implemented. Devising localized topology control algorithms under the physical SINR model remains as a research challenge.

- **Channel Assignment and Routing in Multi-radio, Multi-channel Environments**

A traditional channel assignment problem is what channel should be assigned to a transmission pair in order to enable transmission, mitigate inter-/intra-interference, and improve network capacity. This problem is augmented with another dimension in multi-radio and multi-channel environments: what channel should be associated with each of the radio interfaces a node possesses? Although there have been some preliminary work [1,2], a rigorous treatment of this problem has been lacking. This problem is further complicated, when it is considered in conjunction with routing. Several research effortshave been made to address the joint problem of channel assignment and routing, and various heuristics have been proposed under certain interference models. The challenge, however, remains to consider the problem in an analytic framework under a realistic interference model. Tuning All the PHY/MAC Control Knobs for Spatial Reuse, there are several PHY/MAC attributes that can be used to improve spatial reuse, mitigate interference and maximize network capacity:

a) the transmit power each node uses for communications,
b) the carrier sense threshold each node uses to determine if the shared medium is idle,
c) the channel on which the node transmits,
d) the time intervals in which each node gain access to the channel.

On top of all these, routing also plays an important role in mitigating interference and improving end-to-end throughput. Most existing work has only focused on tuning one or two attributes, in spite of the fact that these attributes actually intertwined with each other. The challenge remains to establish an optimization framework of maximizing the network capacity by adjusting PHY/MAC parameters in all possible dimensions in the design space.

Several routing metrics have been proposed based on the link transmission time that Leverage PHY/MAC Attributes.

- **Overheads Incurred in Cross-Layer Design and Optimization**

Most of the theoretical results that demonstrate the advantage of cross-layer design and optimization in WMNs do not adequately consider the computing and communications overhead thus incurred, i.e., the overhead incurred in collecting information needed for inferring the interference, calculating the route metrics, switching the channels, or scheduling frame transmission. It is thus not clear whether or not the performance gain in engaging multiple protocol entities in the protocol stack or across the network outweighs the overhead thus incurred. An in-depth empirical study on a large WMN is needed to better quantify the overhead.

- **Considering Mesh Client Characteristics in WMNs**

In WMNs, there are roughly two entities: mesh routers and mesh clients. The former is usually stationary and not energy-constrained, while the latter is battery-powered and may move arbitrarily. Most of the existing studies have focused on MAC and routing on mesh routers, without considering the characteristics of mesh clients. Incorporating the end-to-end performance requirements and constraints of mesh clients into WMN design will be an interesting and challenging research issue.

1.2 ROUTING PROTOCOLS AND CHANNEL ASSIGNMENT CHALLENGES FOR WMNS

Unlike ad hoc wireless networks, most of the nodes in WMNs are stationary and thus dynamic topology changes are less of a concern. Also, wireless nodes in WMNs are mostly access points and Internet gateways and thus are not subject to energy constraints. As a result, the focus is shifted from maintaining network connectivity in an energy efficient manner to finding high-throughput routes between nodes, so as to provide users with the maximal end-to-end throughput. In particular, because multiple flows initiated by multiple nodes may engage in transmission at the same time, how to locate routes that give the minimal possible interference is a major issue.

In an MRMC network, performance gains can be achieved if the routing protocol is channel-aware routes takes into account the channels used on each link along the route. Channel Assignment in a multi-radio WMN environment consists of assigning channels to the radios in order to achieve efficient channel utilization and, at the same time, to guarantee an adequate level of connectivity. The problem of optimally assigning channels in an arbitrary mesh topology has been proven to be NP-hard based on its mapping to a graph-coloring problem [10]. Therefore, channel assignment schemes predominantly employ heuristic techniques to assign channels to radios belonging to WMN nodes. Channel assignment strategies categories as:

a) Fixed assignment schemes assign channels to radios either permanently, or for time intervals that are long with respect to the radio switching time. Such schemes can be further subdivided into common channel assignment and varying
channel assignment.

b) In the VCA scheme, radios of different nodes may be assigned different sets of channels [9, 10]. However, the assignment of channels may lead to network partitions and/or topology changes, which may increase the length of routes between mesh nodes. Therefore, in this scheme, channel assignment needs to be carried out carefully.

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2.1 Expected Transmission Count (ETX)

This metric calculates the expected number of transmissions needed to send a frame over a link, by measuring the forward and reverse delivery ratios between a pair of neighboring nodes [4]. To measure the delivery ratios, each node periodically broadcasts a dedicated link probe packet of a fixed size. The probe packet contains the number of probes received from each neighboring node during the last period. Based on these probes, a node can calculate the delivery ratio of probes on the link to and from each of its neighbors. The expected number of transmissions is then calculated as

$$ETX = 1/df \times dr \text{ ---------(i)}$$

Where df and dr are the forward and reverse delivery ratio, respectively. With ETX as the route metric, the routing protocol can locate routes with the least expected number of transmissions.

1.2.2 Expected Transmission Time (ETT)

One major drawback of ETX is that it may not be able to identify high-throughput routes, in the case of multi-radio, multi-rate wireless networks. This is because ETX only considers the packet loss rate on a link but not its bandwidth. ETT has thus been proposed to improve the performance of ETX in multi-radio wireless networks that support different data rates. Specifically, ETT includes the bandwidth of a link in its computation [9],

$$ETT = ETX \times S/B \text{ --------(ii)}$$

Where S and B denote the size of the packet and the bandwidth of the link, respectively. ETT considers the actual time incurred in using the channel.

1.2.3 Weighted Cumulative ETT (WCETT)

What ETX and ETT have not explicitly considered is the intra-flow interference. WCETT was proposed [9] to reduce the number of nodes on the path of a flow that transmit on the same channel. Specifically, let Xc be defined as the number of times channel c is used along a path. Then WCETT for a path is defined as the weighted sum of the cumulative expected transmission time and the maximal value of X_c Among all channels [15], i.e.,

$$WCETT = (1-\beta)\ \sum_{i=0}^{n} ETT_i \ +\ \beta\ \sum_{1}^{c} MAX_c\ X_c \text{ --------------(iii)}$$

Where β (0 <β<1) is a tunable parameter. Moreover, the two terms also represent a trade-off between achieving low delay and high throughput. Reducing the first term reduces the delay, while reducing the second term increases the achievable link throughput. The tunable parameter β is used to adjust the relative importance of the two objectives. Modified Expected Number of Transmissions (mETX) and the Effective Number of Transmissions (ENT) Another issue which ETX does not consider is the effect of short-term channel variation, i.e., ETX takes only the average channel behavior into account for the route decision. In order to capture the time-varying property of a wireless channel, the metrics mETX and ENT were proposed in [11] which took into account both the average and the standard deviation of the observed channel loss rates. Specifically, mETX is expressed as

$$mETX = \exp\ (\mu\Sigma + 1/2\alpha_{\Sigma}^{2}) \text{---------(iv)}$$

Where $\mu\Sigma$ and α_{Σ}^{2} are the average and variability of the channel bit error probability.

1.2.4 LINK QUALITY SOURCE ROUTING (LQSR)

LQSR is a modified version of DSR and aims to select a better route using link quality metrics in single-radio, single-channel wireless networks. LQSR implements the basic functionalities of DSR including route discovery and route maintenance. In addition, a variety of link quality metrics including ETX, Per-hop Round Trip Time (RTT) , Packet Pair and hop count were supported as routing metrics. To the higher layers, MCL appears to be another Ethernet link, although it is a virtual one. To the lower layers, MCL appears to be another protocol running over the physical link. A basic functionality of this protocol is to monitor link quality continuously and change to the path that has the lowest overall cost.

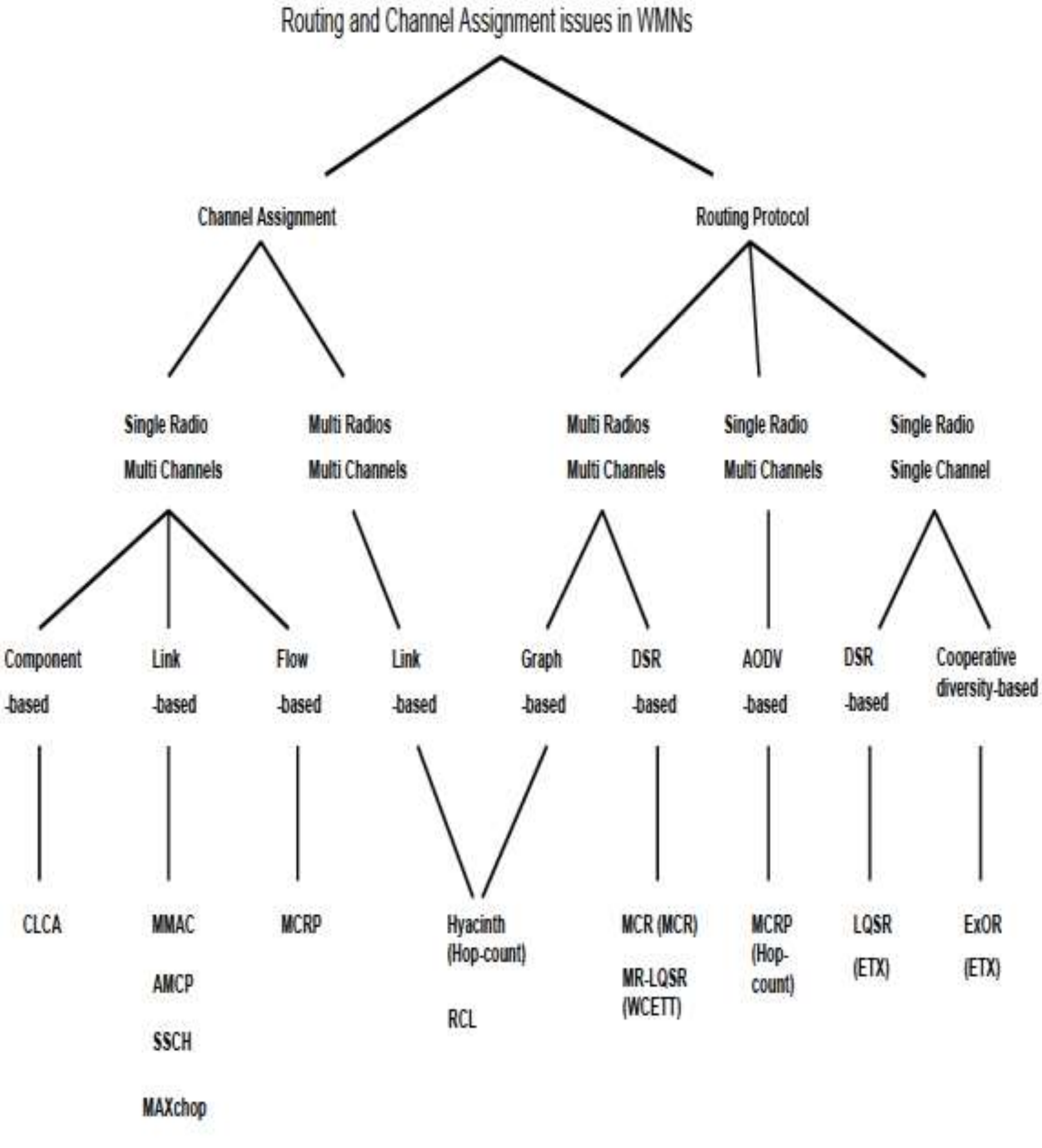

Fig. 1: Taxonomy of channel assignment schemes in wireless mesh networks.

1.2.5 Multi-Channel Routing Protocol (MCRP)

MCRP is a routing protocol that is specifically designed for multi-channel networks with single-radio nodes and exploits a channel switching technique. MCRP assigns channels to data flows rather than assigning channels to nodes. Thus, all nodes on the path on which a data flow traverses are assigned to a common channel. In the route discovery phase, a node with packets to send broadcasts a Route Request (RREQ) packet on each channel in a round robin manner. A RREQ packet contains the channel table and the flow table to be propagated to the destination. The channel table contains the number of times a channel has been consecutively used on a single flow path, and the flow table contains the number of times simultaneous flows have been carried out on a single channel. These tables are used by the destination node to select a feasible and load balancing router. Upon receipt of a RREQ packet, a node also rebroadcasts the RREQ (unless it itself is the destination). Moreover, the node also creates a reverse path to the source and maintains the information of the channel on which the RREQ arrives. Upon receipt of one or more RREQ packets, the destination prepares a Route Reply packet and unicasts it on the selected path. All nodes that are forwarding the corresponding RREQ packet change their operating channels to the channel selected by the destination.

1.2.6 Multi-Radio Link Quality Source Routing (MR-LQSR)

MR-LQSR [10] is essentially the LQSR protocol with the use of the WCETT metric. Similar to LQSR, MR-LQSR also operates in conjunction with the Mesh Connectivity Layer (MCL). It has three main objectives:

(i) the loss rate and the bandwidth of a link should be taken into account for selecting a path;
(ii) the path metric should be increased; and (iii) the path metric should reflect the throughput degradation due to the interference caused by simultaneous transmissions. Towards these objectives, WCETT is considered as a path metric to account for the interference among links in the same channel.

To incorporate WCETT into LQSR, the information including the channel assigned to a link, its bandwidth and loss rate is propagated to all nodes in the network, in the form of DSR control packets.

1.2.7 Multi-Channel Routing (MCR)

MCR is an on-demand, multi-channel routing protocol for WMNs with multi-radio nodes. In order to fully exploit the available channels with a limited number of radios on each node, the protocol uses a switching mechanism to change channels assigned to a radio interface whenever necessary. In particular, two types of interfaces are assumed: fixed and switchable. K interfaces out of a total M interface are fixed interfaces and are designated to some K channels. The remaining interfaces are dynamic interfaces and dynamically assigned to any of the remaining channels. Multiple queues are maintained for all switchable interfaces. Each node maintains a neighbor table and a channel usage list. The neighbor table contains the fixed channels used by the node's neighbors. The channel usage list contains the count of two-hop neighborhoods that are using a channel as their fixed channel. Each node periodically transmits a HELLO packet on all channels, including its fixed channel number and neighbor table. A node receiving the HELLO packet, then updates its neighbor table and channel usage list. The table and list information are used for the switching mechanism to make a decision of which channel is assigned to what interface in the link layer.

II. RELATED WORK

Wireless mesh network (WMNs), with multiple hops and mesh topology, has been emerged as a key including broadband home networking, community networking, business organization networking, and metropolitan area network [1]. Traditional WMNs operate in single-radio single-channel (SR-SC) architecture where each mesh router has only one NIC card and all the mesh routers share one common radio channel. In such a networking , the network suffers from low performance and capacity due to frequent packet collisions and back offs, especially for real-time applications such as VoIP transmission across multi hop WMNs [2].

According to [4], The SR-MC architecture can help to reduce the interference and increase network performance. A required function of the SR-MC solutions is there for each router to dynamically switch between channels along with dynamic network traffic, while coordinating between neighboring nodes to ensure communication on a common channel for some period. However, this type of coordination is usually based on tight time synchronization between nodes, which is difficult to realize in a multi hop WMN. It is noted that the latency in switching the channels with the use of commodity hardware 802.11 NICs can be up to 100 ms.

According to [5], IEEE 802.11a band assign 3 and 12 non-overlapping frequency channels, respectively. Though still there exist significant interference between these standard non-overlapping channels in the current IEEE 802.11 hardware, this problem can be handled by providing better frequency filters in hardware for multi-channel use. So, the use of single-radio multiple-channels (SR-MC) has been proposed to enhance the performance of WMNs .

According to [19], In such architecture, every mesh router is equipped with multiple NICs and each NIC can operate on multiple frequency channels. In MR-MC architecture, multiple transmissions/receptions can occur concurrently, and neighboring links allocated to different channels can carry traffic free from interference. However, MR-MC architecture use poses some new issues. In general, these issues include topology control, power control, channel allocation, link scheduling, and routing

According to [8], the number of available channels is limited to 3 or 12 in IEEE 802.11 frequency bands. This implies that some logical links may be assigned to the same channel. In such case, interference occurs if these logical links are closer to each other, and so these interfering links cannot be active on same time. Furthermore, the number of available NICs are also limited, and hence some logical links within a router require to share a NIC to transmit and receive the data packets. Furthermore, the physical topology of the routers and other constraints in MR-MC WMNs, four important issues that needs attention are summarized in i.e., logical topology formation, interface assignment, channel allocations, and routing decisions.

According to [9], the authors considers the issues with the MR-MC architecture, existing communication protocols, ranging from routing, MAC, and physical layers, need to be revised and enhanced. In physical layer, techniques mainly focus on three research areas: enhance transmission rate, enhancing error resilience capacity, and increasing re configurability and software controllability of radios. In order to improve the capacity of wireless networks, many high-speed physical techniques, such as OFDM, UWB, and MIMO, have been discovered.

III. CONCLUSION AND FUTURE WORK

In this paper, we have identified the key challenges associated with assigning channels to radio interfaces in a multi-radio multi-channel wireless mesh networks. MRMC WMN uses multiple network interfaces per node allows simultaneous transmission and reception on different interfaces tuned to different channels, which can substantially improve multihop throughput. A key issue to be addressed in a multi-radio mesh network architecture is the Channel assignment problem that involves assigning (mapping) channels to radio interfaces to achieve efficient utilization of available channels. After presenting the design issues for WMNs, we have provided a taxonomy of existing channel assignment schemes and summarized this survey with a comparison of the different possible channel and routing architectures for MR-MC WMNs .

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