Channel Assignment for Throughput Optimization in Multi-Radio Wireless Mesh Networks

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Abstract: ***The wireless mesh networks (WMN) consists of mesh routers and mesh clients. The mesh routers have minimal mobility and form the back bone of the network. They also provide integration with mesh client and other conventional networks. In this, thesis proposes a channel assignment algorithm for improving the performance of WMNs. One important criterion for improving the capacity of Wireless Mesh Networks (WMNs) is to use multiple radio interfaces and multiple channels simultaneously. If the traffic is routed without consider the load distribution among the links in the network. It may cause overload to the mesh nodes and this results in the reduction of overall network capacity. The proposed load-aware channel assignment algorithm provides the load balancing for multi-radio mesh networks by using a good routing metric, which improves the throughput, packet delivery rate and transmission rates of the network. The simulation results of this thesis were conducted with the help of NS-2 simulator, showed the capacity improvement that helps distributing the traffic load for efficient resource utilization.***

Keywords: Wireless Mesh Networks, routing metric, Multi-radio, channel assignment

1. Introduction

Wireless Mesh Networks (WMNs) consisting of single radio mesh networks (MRs) operating on a single channel cause decrease in the network capacity as the number of wireless nodes increases [1], [2]. The capacity of the Wireless Mesh Networks (WMNs) can be increased by equipping mesh routers with multiple radios on non-overlapping or partially overlapping IEEE 802.11 channels. On the other hand, a special care is taken in the assignment of channels to the radio interfaces. However, a good channel assignment (CA) algorithm in Multi-radio WMN (MR-WMN) that achieves good performance has many challenges.

The recent developments in the wireless mesh networks (WMNs) have emerged a new communication platform, which provides multi-hop communication as a way of overcoming the energy constraints and inherent mobility patterns of mobile ad-hoc networks. WMNs provide high quality services like multimedia applications, such as video streaming. Wireless Mesh Networks (WMNs) have many advantages over traditional wireless networks. They are robustness, greater coverage, low up-front cost, ease of maintenance and deployment. Another important fact is that, its ability of self-organizing and self-healing [1].

There are many channel assignment algorithms for wireless mesh networks are already defined. The commonly used assignments schemes are static, dynamic, greedy and random based are defined [7], [8], [10]. Here, proposes a load-aware channel assignment and it also supports load balancing. The use of IEEE 802.11 radios, a channel is assigned to a radio interface for a long period of time whenever a traffic demand or topology does not change.

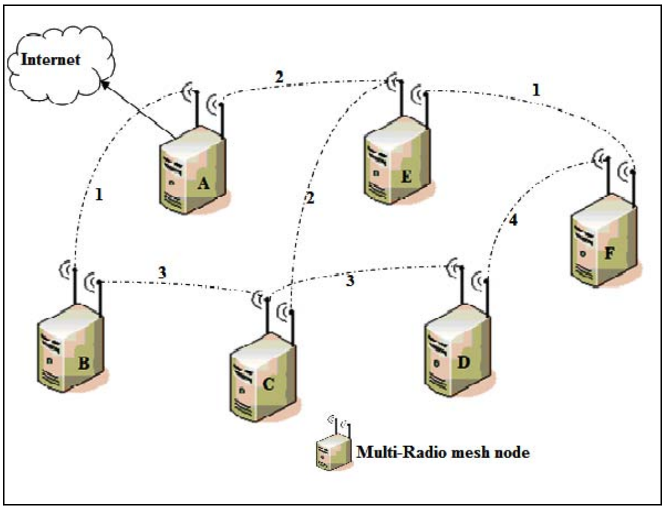

Figure 1: A Multi-Radio WMN using four channels and each node has two interfaces.

The above figure shows a partially connected wireless mesh network in which all nodes have two radios operating on four channels. If a router needs to communicate with any of the nodes by tuning its interface to the destination nodes channel. For example in fig: 1, if node C wants to initiate communication with node E, then node C will tune its interface to channel 2 and establish a wireless link from node C to node E. in the above topology some of the routers act as gateway routers. Here node A is the gateway router, all the other routers can access internet through node A. If node B tends to communicate with the internet, it needs to establish a link to the gateway node A by tuning its interface to channel 1. In such a manner, every node in the network can communicate with any other node by simply tuning the radio interfaces to the desired channel of the communicating node.

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In addition to the channel assignment algorithm, routing metric also play an important role in performance of the network. The various routing metrics are described in [5]. In this, we studied the various routing metrics such as ETT, WEED, RTT, hop count, etc. The expected transmission time (ETT) and the weighted cumulative ETT (WCETT) taken path as the metric are proposed in [4]. Many ad-hoc protocols such as ADOV, DSDV and DSR consider hop count as their routing metric.

2. Channel Assignment Problem

In this, we considering a wireless mesh node consist of **n** mesh nodes. The main purpose of channel assignment problem is to find a channel assignment **A,** such that each communication link is assigned to a unique channel in the mesh network. Also considers the fact that number of different channels assigned to each node is equal to the number of radios on that node. The flow rate of the link e is denoted by $f(e)$ and it transmits at a time period T. The amount of data transfer through that link be $f(e)T$. The capacity of the link is $c(e)$. Then, the time taken for the transmission of that amount of data will be $\frac{f(e)}{c(e)}T$.

The main problem in the every network is the efficient utilization of the network capacity. This problem can be mitigated by equipping the mesh routers with multi radios tuned to non-overlapping channels. However the channel assignment is a challenging problem, because the collocated wireless networks are likely to be tuned to the same channels. The resulting increase in the interference can adversely affect the performance [5]. On the other hand, the Multi-Radio wireless mesh network equips each mesh node with multi IEEE 802.11 interface cards.

The main objective of channel assignment in a Multi-Radio wireless mesh network is to assign each network interface to an available radio channel to transport the network traffic on each link. This is to balance the load and reduce the interference by minimizing the number of interfering neighbors.

3. Routing Metrics

In this section, an overview of the existing routing metrics is described. There are several link quality metrics have been proposed. The performance of wireless mesh networks not only depends on the channel assignment scheme, but also the routing metrics are also involved. They are based on the characteristics of the underlying link such as bandwidth, loss and delay. In the following, briefly review these metrics [4].

3.1 Round Trip Time (RTT) Metric

In this metric, it calculates the round trip delay between the unicast probes exchanged between the nodes. To estimate RTT, each node sends a probe packet to its neighbors. The every probe packet send to the neighboring node contains a timestamp of 500 ms. Every neighbor responds to the probe it receives with an acknowledgement. In this way, the sender can get the value of RTT for that probe. The estimate of the RTT can be calculated by comparing the current value and the previous estimated average. The routing algorithm finally selects the path with least cumulative RTT of all the links along the available path

3.2 The Expected Transmission Count (ETX) Metric

The RTT use link delay in their metrics. But, in the case of expected transmission count (ETX) metric which is based on the expected number of transmissions required to transmit a packet over a link. It also includes retransmissions into account. To calculate ETX, each node measures the probability that a packet successfully reaches the destination is denoted as $\mathbf{d_f}$ and the probability that an acknowledgement is successfully received at the sender, denoted as $\mathbf{d_r}$. the ETX of the link is given by

$$ETX = \frac{1}{d_f * d_r} \quad (1)$$

The routing algorithm selects in a way that the path with least sum of ETX values from its entire constituent links. The value of $\mathbf{d_f}$ and $\mathbf{d_r}$ of each node is measured by sending a probe packet in every second. The ETX metric is isotonic and therefore allows efficient calculation of minimum weight and loop-free paths.

3.3 The Hop Count Metric

This metric is a link quality based and provides minimum hop-count routing. This metric also checks the status of the link periodically. The main advantage of the metric is its simplicity. Once, the topology is known, it is easy to compute and minimize the hop count between a source and a destination node. The measurement of this metrics does not require any additional values like other metrics describe in the section. In the scenarios of high mobility, the hop-count metric can outperform other metrics. This metric also provides high stability and have the property of isotonicity that allows minimum weight paths to be found efficiently.

Among the above discussed routing metrics, the hop-count metric is the traditional routing metric used in most of the common wireless routing protocols like ADOV, DSR (Dynamic Source Routing), DSDV designed for multi-hop wireless mesh networks. So, in the following sections, hop count metric is used as the routing metric for works. But the main drawback of this hop-count metric is that, it does not account for link load, link capacity and the channel diversity experienced by the links. So this may result in high loss ratio and poor performance of the network. But in the proposed channel assignment scheme, i.e. Load Aware channel assignment focuses on these limitations. Therefore, by linking the load aware channel assignment algorithm with the hop-count metric helps in enhancing the network performance such as high throughput, link capacity and low loss ratio.

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4. Channel Assignment Algorithms

In this section, we give an overview of the currently existing channel assignment schemes and the proposed load-aware channel assignment algorithm. When the multi-radio multi-channel wireless mesh nodes are taken into account, new routing protocols are needed for two reasons. The first reason is that routing protocol needs to select not only the optimal path in between the interacting nodes, but also it may consider the suitable appropriate channels on the path. The second criterion is that a common layer design becomes a necessity, because the change of a routing path causes the channel switching in a mesh node. In [5], [6], channel assignment to all radios is considered in a static fashion. Their channel assignment algorithms are localized designed for a mesh network with a more general peer to peer traffic pattern.

4.1 Static Channel Assignment

In a static channel assignment strategy, each interface is assigned to a channel for long durations. There are mainly two types of approaches in this category. The first is the common channel approach in which the radios interfaces of all the nodes in a network are assigned to common channels. In the second strategy, the radio interfaces in different nodes may be assigned to different channels. This is a varying approach. Hence, in this type of strategy, nodes sharing a common channel on at least one of their radio interfaces can communicate each other, while other cannot. Therefore, the decision of which node can communicate in the network can affect the performance of the network.

4.2 Dynamic Channel Assignment

In this type of strategy, any interface assigned to any channel can frequently switch the channel each other. A network using such a strategy needs some kind of synchronization mechanisms to enable communication between nodes in the network. In such mechanisms, all the nodes in the network should periodically visit a predetermined rendezvous channel [7] to negotiate channels for the next phase of the transmission. The advantage of this channel assignment scheme is the ability to switch an interface to any available channel. So we can reduce the use of interfaces. In this case, the switching of the channel will consider the interference problem. The main challenge involved is the channel switching delays.

4.3 Random Channel Assignment

Random channel assignment, from the name it deals with allotting of channels randomly to the interfaces without taking any criteria into account. When implementing such type of assignment to all available **K** channels in a network, there is a possibility of the complete non-convergence in the network. So, necessity of modifying random channel assignment is needed. The channel assignment algorithm is performed on the basis of „HELLO" packet exchange between the nodes.

IP (32 bits)				
Hello (0 bits)	Channel	Net. mask	Hello interval	Neighbor ID

Figure 2: HELLO packet format**.**

The above figure shows format of HELLO packet. If there are two nodes $\mathbf{v_i}$ and $\mathbf{v_j}$ forming a link **e** have a free radio. Then, we randomly assign a channel from all the possible available channels **K**.

4.4 Greedy Channel Assignment

In this algorithm, when a node needs to communicate by greedily selects the channel. But it does not straight away select the channel as in the case of random channel assignment. The channel assignment algorithm waits for some random amount of time. This assignment also tries to minimize the overall network interference [5], [9]. We assign all the interfaces to the same channel in the single channel case. So, we have an initial assignment with maximum interference and try to optimize the interference by changing one link at a time with respect to the constraints.

On the each iteration of the algorithm, we randomly select an optimized link. Then, we try all the possible combination of channel with link to achieve minimum network interference. The channel assignment algorithm selects the least interference channel as in the case of random and greedy channel assignment.

4.5 Load-Aware Channel Assignment

This algorithm takes a typical approach by jointly considering both the channel assignment and routing of traffic demands. The algorithm also supports the load balancing capability. Given the mesh network **G(V,E)** and the traffic profile { $\mathbf{l(u_i,v_i)}$ | **i** = 1,2,…,m}, the problem is to find both channel assignment scheme **{ A(u) | u € v}** and the routing for each flow, such that the traffic demand specified by the traffic profile can be satisfied [6]. In the simulation work, hop-count metric is taken for the purpose of routing.

4.5.1 Load balancing

The main goal of load balancing in load-aware algorithm is to enhance the data flow throughout the network and to avoid the bottle neck links over the mesh network. The load balancing means the ability of a router to transmit packets to a destination over more than one path. Load balancing guarantees equal traffic flow across all the links in the network. Sometimes, there is problem associated with arrival of packets at the destination. The differential delay may cause out of order receptions of packets. So, the load balancing should be performed by looking up the route table and least used interface for each packet.

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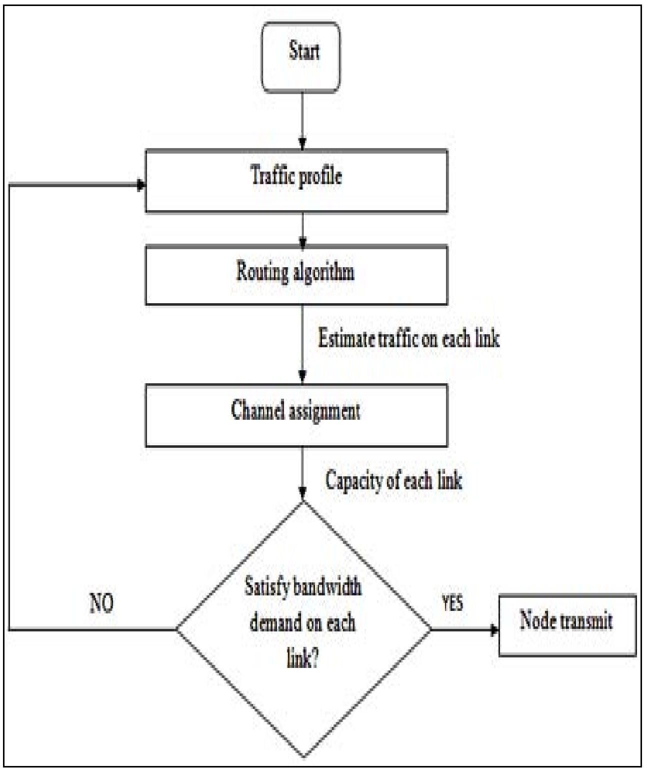

Figure 3: Load-aware algorithm.

The fundamental idea of the load-aware algorithm is illustrated in fig: 3. In this algorithm it starts with an initial estimation on traffic load on each link. Routing algorithm finds the paths between the source and destination nodes. Then, the channel assignment algorithm checks the load on each link and also checks the capacity of the link. Given each links traffic load under the routing scheme. Each interface is assigned a channel such that the link load can be satisfied as much as possible in the resulting network. When more than one link satisfies the traffic load, traffic will be transmitted to the destination node via multiple links.

5. Performance Evaluation

We evaluated the performance of load-aware channel assignment in Multi-Radio WMNs by using ns-2 simulator. In addition, we compare load-aware channel assignment with some algorithms: random and greedy. All flows were CBR flows with 512 packets. The transmission range is 250m. We use the hop-count metric as the routing metric for the simulation.

Table 1: Simulation parameter value

Parameter description	*Value*
Traffic type	CBR
Packet size	512 bytes
Buffer size	50 packets
Number of nodes	20
Simulation area	500m * 500m
Simulation time	300s

5.1 Simulation Results

In this section, we analyze the simulation results and evaluate the performance of the three channel assignment algorithms. We will give some definition if the parameters which we use to evaluate the performance.

1. Throughput: it is defined as the total number of unicast data communication bits.

2. Delay: the time difference between packets sent from the source node to the destination node.

$$Delay = Packet_{Time_{sent}} - Packet_{Time_{received}} \quad (2)$$

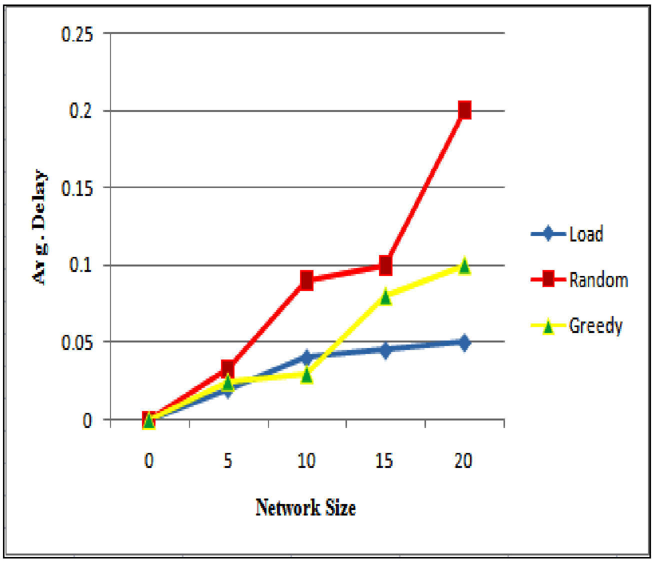

Figure 4: Average delay comparisons of three channel assignment algorithms.

The simulation results show that, load-aware channel assignment algorithm gives better performance over the random and greedy channel assignment schemes. The throughput of the network become more stable as the time extends.

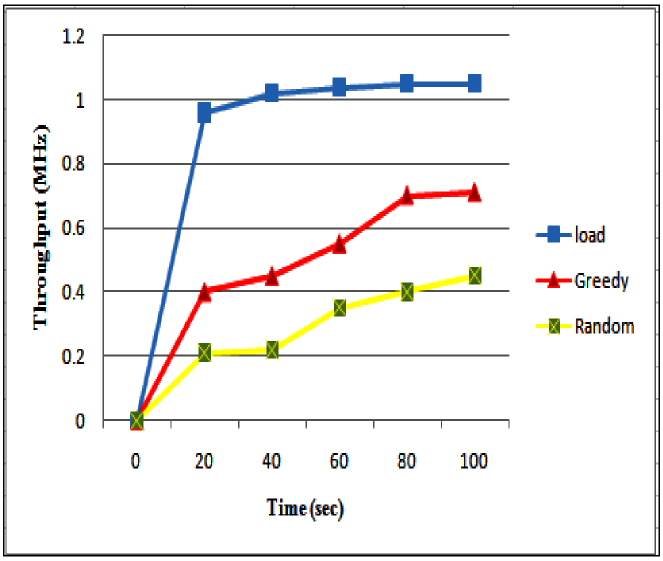

Figure 5: Throughput comparisons of three channel assignment algorithms.

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6. Conclusion

In this paper, we presented the major problems in Multi-Radio WMNs and major solutions for solving load-aware routing and load balancing. Also, we described the requirements that routing metrics need to ensure the capacity of WMNs. In addition, the studies of various channel assignment schemes are conducted. Demonstrate the performance of channel assignment algorithms via ns-2 simulation results. Finally, the performances of these channel assignment algorithms are compared. It appeared that load-aware channel assignment gives best performance among all the channel assignment schemes.

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