A TRAFFIC CONSCIOUS CHANNEL REALLOCATION ALGORITHM FOR WMN

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Abstract*: Wireless mesh networks (WMNs) have attracted a lot of interest from both the international research community and industries. This sort of an interest from industries is due to the possibility to cover metropolitan areas without a wired infrastructure that makes WMNs a cost-effective solution to implement. The channel assignment problem has been also shown to be interdependent with the routing problem. This is nothing but the problem to determine the amount of traffic flow to be routed on each link. This kind of a relationship raises the need to recompute the channel assignment every time the traffic pattern changes. Researchers, instead, have been attracted by the challenging issues related to the configuration and organization of WMNs. The greatest of such issues is the assignment of channels to radios in case mesh routers are equipped with multiple radios. And the multiradio configuration is becoming increasingly regularly found, while routers may exploit the availability of multiple radios to simultaneously transmit and/or receive on different channels. As shown by the experiments that were conducted, and such a time may not be negligible, because of the resistance of routing protocols designed for wireless ad hoc and mesh networks to rapidly flagging a link as established or lost. This consideration, along with the observation that channel assignment algorithms may be suboptimal, and have led to the design of a channel reassignment algorithm that takes the current channel assignment into account and attempts to cope with the new traffic pattern in the best manner possible while modifying the channel on a limited number of radios. The channel reassignment algorithm is illustrated and evaluated by its performance by means of both simulations and experiments with real hardware.
***Keywords:* Wireless mesh network (WMN), Multiradio, Channel assignment algorithm, Routing problem.**

I. INTRODUCTION

Wireless Mesh Network (WMN) consists of several radio nodes which are arranged in the mesh topology. The components of wireless mesh networks are mesh routers, mesh clients, gateways. Even though one node present the WMN could not operate for long time, the other nodes in the network can communicate directly or through some transitional nodes. Wireless mesh network is an extraordinary kind of wireless ad-hoc network. WMN can offer dynamic and cost efficient connectivity in certain places.

Wireless mesh networks (WMNs) have attracted a lot of interest from both the international research community and i. This kind of an interest from industries is due to the possibility to cover metropolitan areas without a wired infrastructure that makes WMNs a cost-effective solution to put into practice. As an alternative, researchers have been attracted by the challenging issues related to the configuration and management of WMNs. The greatest of such issues is the assignment of channels to radios in case mesh routers are equipped with multiple radios. Multi radio configuration is becoming increasingly common. In [1] it has been shown that the assignment of channels is not independent of the routing problem. Certainly, nodes using the same channel in a neighborhood have to share the channel capacity and hence the amount of bandwidth available on a link depends on how many nodes are using the same channel in the neighborhood. The way channels are assigned affects the amount of bandwidth available on links hence the channel assignment problem and the routing problem should be studied together. The joint channel assignment and routing problem has been shown to be NP-complete. Therefore, t h e proposals that recently appeared in the literature addressing such joint problem solve the channel assignment problem and the routing problem separately. Generally, an approach is to first solve the routing problem. This is a solution to - how to determine the amount of flow (referred to as the flow rate) to be routed on every link, after which to solve the channel assignment problem, this is the solution of how to assign channels in such a way that the resulting bandwidth available on each link exceeds the link flow rate.

Since the assignment of channels depends on the set of flow rates, there is a need to recompute it upon a variation of the traffic load. However, frequent re computations of the channel assignment are n o t desirable. Certainly a new execution of the channel assignment procedure does not take the current assignment into account and thus will likely return a completely different assignment of channels with respect to present one. Implementing the new assignment will thus require changing the channels assigned to quite a few radios. The switching of channel on a radio breaks the network connectivity for a much longer time than that required by the radio hardware to shift to the new frequency. Certainly, routing protocols take some time to assess that a previously active link is no longer available or a new link is actually consistent. It is necessary condition due to the varying conditions of the w ireless medium and is done to avoid routing oscillations. Therefore, when a radio is assigned a new channel, it is expected that the routing protocol takes some time to start using the links established on the new channel instead of the links on the previous channel. These resulting packet losses may also induce the TCP entities to decrease the congestion window and increase the retransmission timer that in turn provides effective lowering in the throughput for an additional period.

Switching channel on a radio therefore results into pruning all the links using that radio from the network topology for a certain period of time. Accordingly, it is clear that the more radios switch channel will result in the higher impact on the network performance. We present a simple heuristic that takes the current channel assignment into account and aims to adjust at most a configurable number of channels to cope with a variation in the set of flow rates in the best manner possible for the same reason. During a thorough simulation study, it is shown that our heuristic, apart from being beneficial in the short term due to the limited number of required channel switches, also guarantees a higher throughput in the longer term, with regard to both other channel assignment algorithms and the strategy of leaving the channel assignment unchanged. Certainly, as the channel assignment problem is NP-complete [1], most existing algorithms are heuristics that only provide a suboptimal resolution. This channel reassignment algorithm, as an alternative, starts from one such solution and makes some adjustments to find a better solution.

Another contribution of this paper is an analysis of the overhead (introduced by the IEEE 802.11 medium access function). This has led to the identification of a parameter, which is the total utilization of a collision domain, which has a strong (negative) correlation with the network throughput. Therefore, we considered the minimization of the maximum total utilization over all the collision domains as the objective of our channel reassignment algorithm. In addition, the aforementioned analysis enables us to find a reference value for the maximum total utilization that ensures that the network is actually able to carry the offered traffic load. Therefore, the condition that the maximum total utilization exceeds such reference value can be used as indication that a channel reassignment is needed.

II. RELATED WORK

Many proposals aim to minimize some network-wide measure of interference and do not study the channel assignment problem in conjunction with the routing problem. For example, in Interference-Aware Topology Control and QoS Routing in Multi-Channel Wireless Mesh Networks, the objective is to find a channel assignment that minimizes the size of the largest collision domain subject to the constraint that the induced graph must still be K-connected. In Multi-Radio Wireless Mesh Networks a centralized algorithm is presented in Interference-Aware Channel Assignment that also takes the traffic generated by mesh clients into account. The Superimposed Code Based Channel Assignment in Multi-Radio Multi-Channel Wireless Mesh Networks considers an interference-free channel assignment is sought by using superimposed codes. And MesTiC is a rank-based channel assignment, in which the rank of a node is a function of its aggregate traffic and its number of hops from the gateway and also its number of radio interfaces. The Minimum Interference Channel Assignment in Multi-Radio Wireless Mesh Networks has both centralized and distributed algorithms are presented that aim to minimize the number of pairs of links that are interfering. In Architecture and Algorithms (for an IEEE 802.11 Based) Multi-Channel WMN, a distributed channel assignment algorithm and a distributed routing protocol are proposed. Realistic, Distributed Channel Assignment and Routing in Dual-Radio Mesh Networks presents a distributed protocol for channel assignment and routing in dual-radio mesh networks.

Other proposals study the joint channel assignment and routing problem. In Centralized Channel Assignment and Routing Algorithms for Multi-Channel Wireless Mesh Networks [3] an iterative routing algorithm based on traffic profiles is proposed. In Joint Channel Assignment and Routing for Throughput Optimization in Multiradio Wireless Mesh Networks [4], an approximate solution for the joint channel assignment and routing problem is developed which optimizes the network throughput subject to fairness restrictions. The problem how to verify the feasibility of a given set of flows between source-destination pairs is investigated in Characterizing the Capacity Region in Multi-Radio Multi-Channel Wireless Mesh Networks [5].

A distributed joint channel assignment, routing and scheduling algorithm is presented in Distributed Joint Channel-Assignment. Scheduling and Routing Algorithm for Multi-Channel Ad-Hoc Wireless Networks [6]. In [7] the authors develop a centralized solution to the joint logical topology design with interface assignment and channel allocation and routing problem.

There has been also some work on the channel assignment problem in wireless sensor networks. Owing to hardware limitations, all sensors have a single radio interface due to which the proposed algorithms usually assign channels in a dynamic conduct. A traffic-aware channel assignment algorithm is proposed in Traffic-Aware Channel Assignment in Wireless Sensor Networks [8], while a middleware positioned between the MAC and PHY layers is proposed in [9] to find the best channel at runtime and communicate it to a single-channel MAC protocol. In Radio Interference Detection in Wireless Sensor Networks (RID) [10] a protocol to detect the radio interference among nodes and a collision-free TDMA schedule based on the results of such detection are proposed.

Disadvantage
All the papers mentioned so far, nevertheless, do not consider

the problem how to reconfigure the WMN after a change in the traffic flows. This has been tackled in a few methods. The approach in [2] does not consider the standard CSMA/CA access technique but assumes the existence of a link layer synchronization among the nodes which enables them to organize their data transmissions in different time slots with no contention.

Proposed System

The proposed algorithm reconfigures the channel assignment and the link scheduling as a consequence of a change in the traffic matrix. The approach assumes the standard contention-based access technique and hence does not perform link scheduling instead. Previously a distributed channel reassignment heuristic was proposed that aims to cope with the traffic variation due to mesh clients' handoffs. The proposed approach solely only makes a channel switch on the edge mesh routers aggregating clients' traffic and does not ensure that all the node pairs remain connected after the channel switch, this requires changes in the routing tables of the mesh routers concerned. With regard to our previous approach, we present an enhanced version of the channel reassignment algorithm under many aspects (reconfiguration of transmission rates, enhanced definition of the link priorities, etc) and a more accurate and complete performance evaluation.

III. WORKING OF PROPOSED SYSTEM

Total Utilization of a Collision Domain

The effect of the interference is to prevent simultaneous transmissions over neighboring links using the same channel. Therefore, the throughput that can be achieved across a wireless link (denoted as flow rate in the following) is affected by the amount of traffic transmitted on the neighboring links. Known a set of links L such that no two links can be transmitting simultaneously, the goal is to determine a condition establishing whether the associated flow rates can be actually achieved or not. In a given time interval of duration T, every link e 2 L with a flow rate f(e) has to carry an amount of data equal to F(e)T.

The below equation (1) is A Condition on the Flow Rates of Interfering Links

$$\Omega(e) = DIFS + T_{slot} \cdot N_{slot} + 2 \cdot T_{PLCP} + \frac{HLEN}{c(e)} + SIFS + \frac{ACK}{R_{ctrl}}, \quad \text{..............................(1)}$$

Total Utilization of a Collision Domain

To apply such condition to a network topology, it is required to determine all the sets of links such that no two links in a set can be transmitting concurrently. For this reason, we might build a conflict graph vertices. These represent network links and edges connect vertices representing interfering links to find all the maximal cliques in the conflict graph. Though, finding all the maximal cliques in a graph is a known NP complete problem. In order to lower the complexity, the notion of collision domain of a link is considered. Our objective to have total utilization of all the collision domains below a threshold (that is equivalent to have the maximum among the total utilizations of all the collision domains below that threshold) is supported. It shows that the achieved throughput is very close to the offered load until the maximum total utilization over all the collision domains is below a certain threshold. From this time forth, by maximum total utilization, the maximum among the total utilizations of all the collision domains is meant.

We define the collision domain of a link $u \xrightarrow{c} v$ as the set of all the links that interfere with it. The equation formally is,

$$\mathcal{D}(u \xrightarrow{c} v) = \left\{ x \xrightarrow{c} y \in E \mid \frac{G_{uv} P(u \to v)}{G_{xv} P(x \to y) + n_v} < \gamma_{c(u \xrightarrow{c} v)} \right\} \cup \{ v \xrightarrow{c} u \}. \quad \text{..(2)}$$

Minimum Variation Channel and Rate Reassignment Algorithm

MVCRA-R is given the current assignment of channels, the new set f(e) of flow rates and the Max Num Changes parameter that determines the maximum allowed number of changes to the channels assigned to the radios. The total utilization of all the collision domains as determined by the current channel assignment and the new set of flow rates are computed to determine what radios need to be assigned a new channel.

All the links of the communication graph are then inserted into a priority queue Q and are extracted one by one in decreasing order of priority. This priority of a link l is given by its flow to capacity ratio times the number of links whose collision domain includes l and has a total utilization above a given threshold. The motivation is that we want to extract first those links that allow as many collision domains as possible to benefit from a channel switch. The variable 'Num Changes' holds the current number of channel adjustments and should not exceed the 'Max Num Changes' parameter.

IV. SIMULATION RESULTS

The Network Simulator ns-2.28 is used to analyse the system. The NS2 is a discrete event time driven simulator which is used to analyse the performance of a network. The following parameters give the efficiency of the proposed system.

Packet Delivery Ratio:

The packet delivery ratio is one of the Quality of Service

(QoS) metric to evaluate the performance of network. Low PDR depletes the network performance. Figure.2 shows that the proposed system has a good packet delivery ratio in spite of the channel assignment and rate re-assignment process.

The working flow diagram of the proposed scheme is illustrated in the figure below.

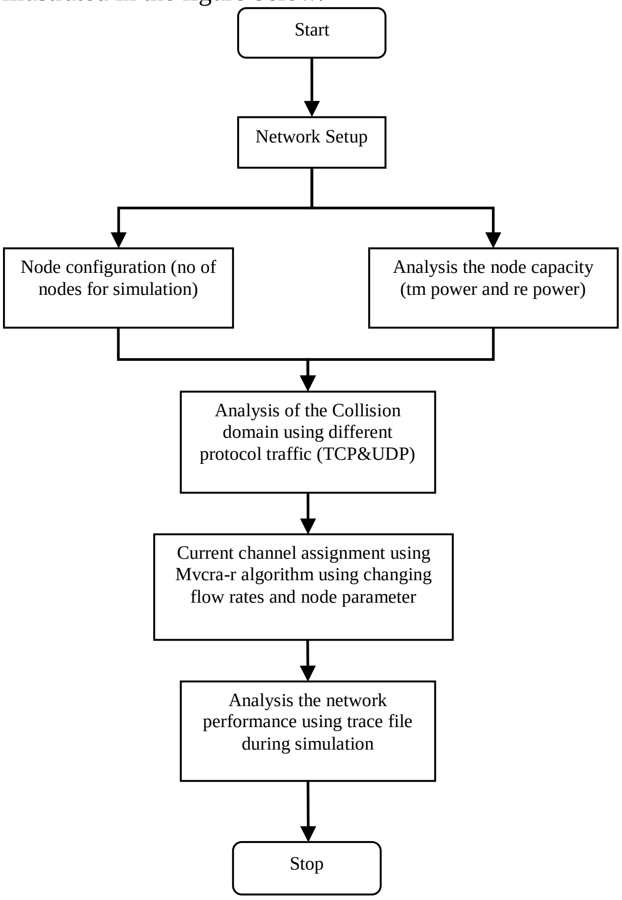

Figure 1. Working Flow

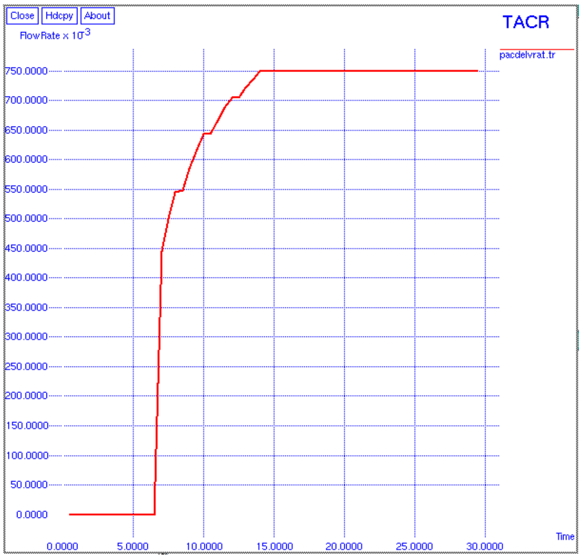

Figure 2. Packet Delivery Ratio

Packet Loss Ratio:

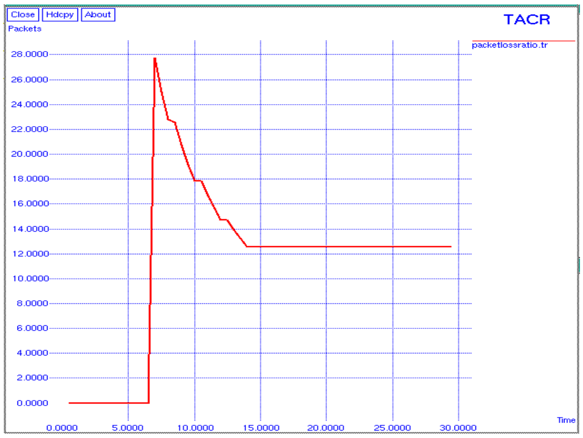

Figure 3. Packet Loss Ratio

The Packet Loss ratio is the maximum number of packets possible to be dropped by a node. Figure 3 shows that the packet loss is optimal during the beginning of data transmission but is minimized as the rate adjustment process of the proposed scheme is incorporated.

Packet Delay:
Packet Delay is the delay occurred during data transmission and it is given in figure 4.

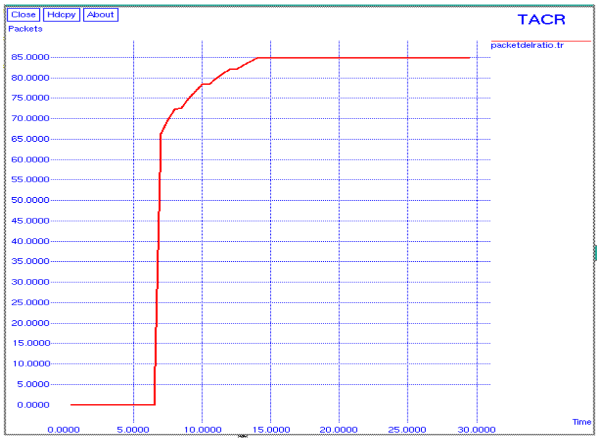

Figure 4. Packet Delay

End-to-end Delay:
It can be observed that MVCRA-R outperforms the other algorithms from the figure 6.

Radios Changed:
The number of radios changed after maximum utilization is minimized by the MVCRA-R algorithm compared to any other algorithm. This is shown in figure 7.

The delay occurred for a packet to transmit from source to destination is called end-to-end delay. The end-to-end delay of the above described system is obtained in figure 5.

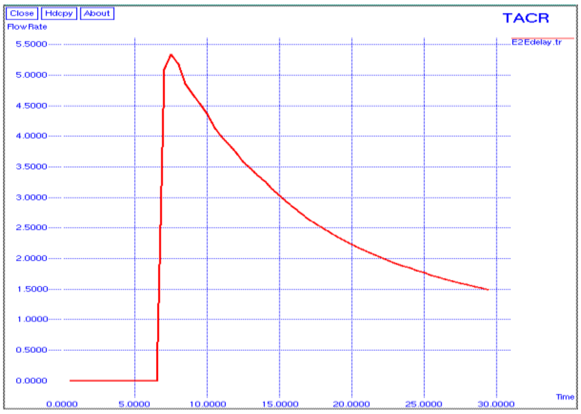

Figure 5. End-to-end

Normalized UDP throughput:
The maximum total utilization and average throughput normalized to those achieved with the initial channel assignment.

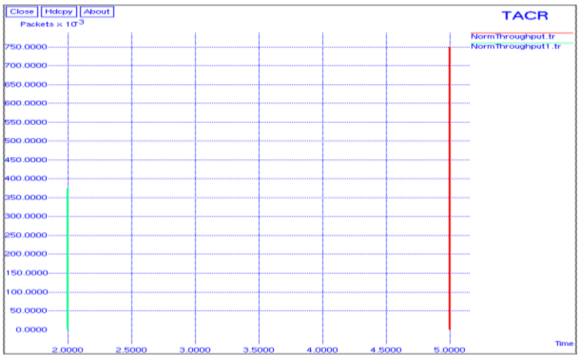

Figure. 6 Normalized UDP throughput

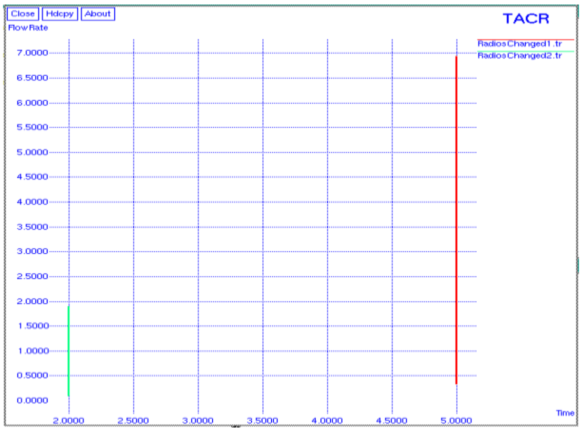

Figure 7. Number of Radios Changed

V. CONCLUSION

In this paper, the MVCRA-R algorithm that takes the current channel assignment and the new set of flow rates into account was analyzed and attempts to minimize the maximum total utilization over all the collision domains while constraining the number of radios that can be assigned a new channel. With respect to MVCRA the MVCRA-R leverages the possibility to adjust the link transmission rates and presents some enhancements such as an improved definition of the link priorities.

We performed extensive simulation studies that confirmed that MVCRA-R roughly meets the constraint on the maximum allowed number of radio changes and outperforms both MVCRA and a channel assignment algorithm such as FCRA in terms of maximum total utilization and network throughput. In future, the duty cycle operation of the MVCRA-R algorithm can be performed and analysed.

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