A Batch Based Call Admission Control Algorithm for Wireless Mesh Networks

Nika Naghavi[1] and Vasilis Friderikos

Centre for Telecommunications Research, King's College London

Abstract: In this paper a multi-hop infrastructure based wireless mesh network (WMN), consisting of mesh access points (MAPs) and mesh client (flow) with a hierarchical architecture is considered. The association of each flow-MAP and the multi-hop backhaul routing from the associated MAP to the Gateway, determine the available bandwidth for admitting or rejecting a flow. The main focus of this paper is the investigation of joint call admission control and routing algorithms in order to maximize the total revenue in the network. To this end, a batch based greedy call packing algorithm is proposed and its performance is evaluated.

1. Introduction.

Wireless mesh networks (WMNs) are multihop wireless networks that provide wireless connectivity for a vast number of applications from personal and local to metropolitan area. WMNs consist of mesh router and clients. Benefiting from self-forming, self-healing and self-organization capabilities, have made WMNs a vigorous area of research over the last few years [1].

Admission control has been comprehensively studied in cellular networks. The majority of CAC schemes proposed for cellular networks are based on the concept of using guard channel information. A revenue-based CAC for wireless cellular networks, using channel reassignment is proposed in [2], where the study demonstrates the relationship between the number of guard channels, reassignments and total revenue.

In WMNS routing and CAC are highly interrelated and therefore a joint design scheme is required to take into account the available resources at the serving node and also the routing path within the WMN. An admission control algorithm based on the connections' rate and delay is proposed in [3]. The authors propose a CAC scheme that first constructs a tree-based topology connecting wireless backhaul nodes to the wired gateway, the admission decision is then carried out in order to maximize the total revenue with regards to the rate and delay of the connections. A mobile agent based handoff approach for WMNs is suggested in [4], where each mesh client is facilitated with an MA residing on its current router. In this scheme if a hand over to a new mesh router is necessary by the mesh client, the mobile agent will move to the new mesh router and reserve a communication channel. A joint optimization of association, backhaul routing and bandwidth allocation in WMNs, taking the access and backhaul links capacity and wireless interference is addressed in [5]. The objective of this work is to maximise the network throughput as well as assurance of a fair bandwidth allocation amongst all the mesh clients. Since in this work association, backhaul routing and bandwidth allocation are considered jointly, in order to tackle with the complexity of the problem some vital constraints are disregarded. In [6] the revenue based connection admission control and routing has been modelled as an SMDP. It assumes pre-computed k paths for each origin-destination, and also uses resource reservations for classes or services possessing higher priority. However the work does not delve into the effect of pricing on the performance of the system such as throughput, load or connection blocking probability.

In WMNS the traffic can be bottlenecked by either the access link or by the backhaul links. Thus, the central theme of this paper is to design a joint admission control and routing that avoids the bottlenecks. Next generation of wireless networks offer a vast range of multimedia services to the users; hence it is vital to design a call admission control algorithm that besides satisfying the users' QoS requirements, aims at maximizing the revenue of the network operator. Under this perspective, we define the problem as a maximisation problem, where the total revenue from all the carried connections in the network needs to be maximised while taking into account the bandwidth constraints of access and backhaul links.

[1] Corresponding author: nika.naghavi@kcl.ac.uk

2. Problem Definition.

We consider a wireless mesh network with *M* MAPs and *N* clients (or flows) as a connectivity graph G (*V; L*), where *V* is a set of vertices (wireless nodes) and *L* is the set of edges or transmission links that satisfy the SINR threshold criterion. We assume that each of the wireless nodes transmit with the same fixed transmission power and therefore a fixed transmission range.

L = {(u; v) |u; v ∈ V s.t. u being in the transmission range of v and vice versa} (1)

The capacity of each MAP's access link is denoted as c_j, where $j \in m = [1,2,...,M]$. We assume that routing paths are pre-constructed and we focus on constructing *k* shortest path algorithms using Dijkstra's algorithm. The cost metric used is the free path loss for a link (*i; j*). We use w_i and p_i to denote the amount of bandwidth each flow $i \in n = [1,2,...,N]$ is requesting and the profit associated with admitting this connection respectively. The following are the transmission range, map of nodes and shortest paths and the decision variables matrices:

$$D_{ij} = \begin{cases} 1 \ \ if \ \ flow \ \ i \ \ is \ \ within \ \ transmission \ \ range \ \ of \ \ MAP_i \\ 0 \ \ Otherwisw \end{cases} \quad (2)$$

$$sp^v(jk) = \begin{cases} 1 \ \ if \ \ sp_k \ \ of \ \ MAP_j \ \ passes \ \ through \ \ node \ \ v \\ 0 \ \ Otherwisw \end{cases} \quad (3)$$

$$x_{ijk} = \begin{cases} 1 \ \ if \ \ flow \ \ i \ \ is \ \ assigned \ \ to \ \ sp_k \ \ of \ \ MAP_i \\ 0 \ \ Otherwisw \end{cases} \quad (4)$$

Associating a flow to a specific MAP and routing it through backhaul to the gateway, requires enough capacity in the access link and backhaul links of that MAP. Jointly solving the admission control and routing in a wireless multihop environment, given a set of nodes and demands, is a complex optimization problem [3]. Therefore, we decompose the problem into routing (path construction) and admission control, thus solving them separately.

Once the routing paths are constructed, we associate each flow with an appropriate MAP. A flow can be admitted to a sp_k of a MAP_j, if there is enough capacity on the access link of MAP_j and all the intermediate nodes on the sp_k.

4. Routing Algorithm.

In this work we use *k* shortest routing paths from the gateway to each MAP , which are pre-constructed in a separate phase using Dijkstra's algorithm. The admission of demands is then carried out assuming that our environment is interference free. The routing algorithm employed in this paper, manages to find *k* shortest paths for each source-destination pair based on the proposed algorithm in [7].

In addition, *k* shortest paths are constructed rooted at the gateway to each MAP. . The k shortest paths are not node-disjoint and they might share an intermediate node; therefore in order to avoid routing traffic over these nodes, the bottlenecks in the backhaul should be checked prior to associating a flow to a MAP. Equation (3) is a matrix that maps all the shortest paths and intermediate nodes in the backhaul, using this matrix the shared intermediate nodes can be identified.

5. Greedy Call Packing Algorithm.

The greedy call packing (GCP) algorithm chooses the local optimum and assumes that it is the global optimum and progresses making one greedy choice after another.

The following steps are implemented in the greedy algorithm in this work:

Step 1: First the greedy factor of all the flows is calculated as follows:

$$\frac{p_i}{w_i}$$

Step 2: The flows are sorted so that:

$$\frac{p_1}{w_1} > \frac{p_2}{w_2} > \ldots > \frac{p_n}{w_n}$$

Step 3: Add all the flows until it reaches the critical flow s, where s is:

$$s = \min\{J : \sum_{i=1}^{J} w_i > c\}$$

Step 4: The last flow admitted, which is the critical flow, is discarded (rejected). The search continues until either access link or backhaul link is fully loaded or there is no enough capacity available to admit any more flows.

6. Performance Evaluation.

Our simulation scenario consists of a wireless mesh topology with a randomly placed MAPs and randomly distributed flows in a manner that each flow is within the transmission range of at least two MAPs. In our topology mesh network is deployed within a 1 km^2 rectangular area, containing three MAPs and one gateway; there are ten intermediate nodes (APs) that provide the backhaul routing. We use a uniform random generator to generate the bandwidth of the flows between 128Kbps and 4.096Mbps. Each intermediate node in the backhaul has the equal capacity of 15Mbps and each access link has a total capacity of 30Mbps.

Once the topology is deployed using the Dijkstra algorithm $k = 2$ shortest paths were constructed from each MAP to the gateway. Below the topology employed in this work is shown:

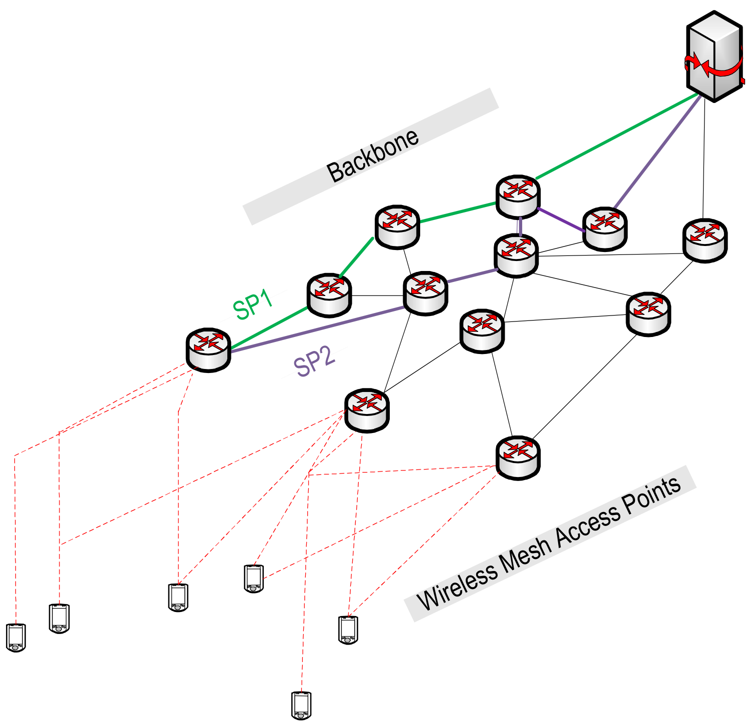

Figure 1: Topology of the WMNs deployed in this project.

Using the pre-computed paths, a solution in a reasonable computational time through incorporating the GCP algorithm is achieved. We compare the results of batch based GCP with an on-line scheme, where calls arrive one by one and are admitted untill the capacity is reached. This is shown in the figure below:

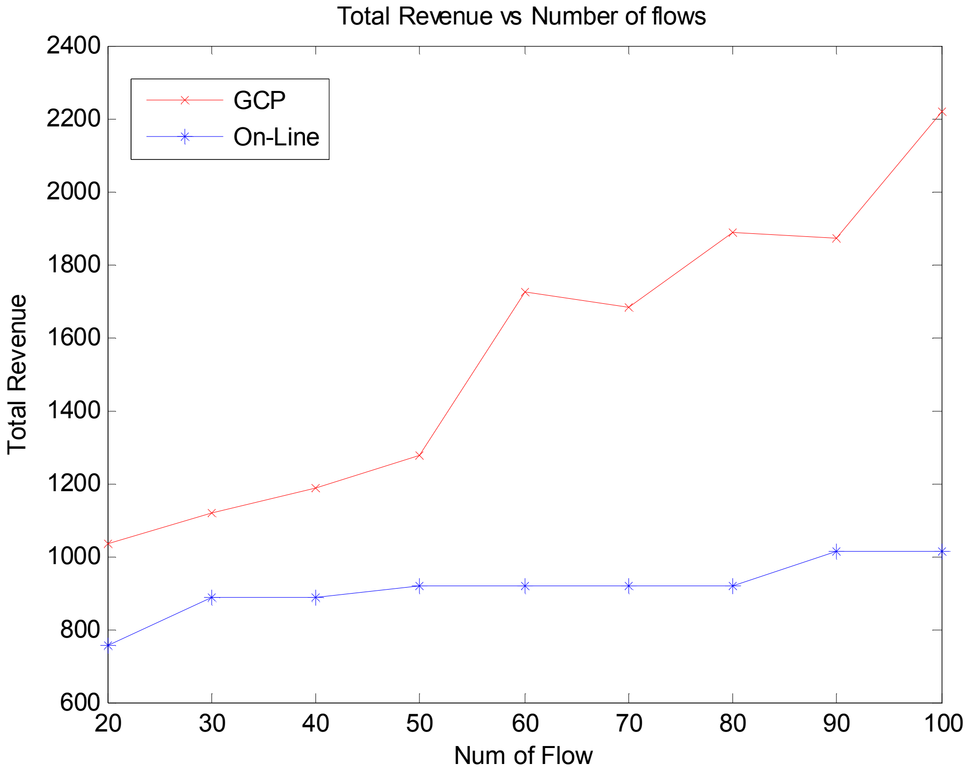

Figure 2: Total revenue against number of flows using GCP and on-line scheme.

7. Conclusions.

This paper proposes a joint call admission control and routing in WMNs that aims to maximise the total revenue of the network provider. In our proposed scheme upon arrival of a flow, both the capacity of access link and the intermediate nodes on the routing paths are considered and a decision as to admit or reject the flow is been made. It is observed that batch based GCP manages to find a better solution (higher revenue) for this problem comparing to the on-line scheme where calls arrive one by one.

An interesting extension on this work would be the use of a meta-heuristic algorithm and comparison of its results with the GCP.

8. References.

[1] I. F.Akyildiz and X. Wang, "A survey on wireless mesh networks," IEEE Communications Magazine, vol. 43, pp. S23–S30, Sept.2005.
[2] S. Nelakuditi, R. Harinath, S. Rayadurgam, and Z.-L. Zhang, "Revenuebased call admission control for wireless cellular networks," in 1999 IEEE International Conference on Personal Wireless Communication,1999.
[3] S. Lee, N. Girjia, M. Pal, G. Wilfong, and L. Zhang, "Admission control for multihop wireless backhaul networks with qos support," in IEEE Wireless Communications and Networking Conference, WCNC 2006, April 2006.
[4] B. Rong, Y. Qian, K. Lu, and M. Kadoch, "Call admission control for mobile agent based handoff in wireless mesh networks," in IEEE International Conference on Communications, ICC, May 2008.
[5] L. Luo, D. Raychaudhuri, H. Liu, M. Wu, and D. Li, "Joint association, routing and bandwidth allocation for wireless mesh networks," in IEEE GLOBECOM 2008, 2008.
[6] S. Zhang, F. Yu, and V. Leung, "Joint connection admission control and routing in ieee 802.16-based mesh networks," in IEEE International Conference on Communications, ICC, May 2008.
[7] R. Mewanou and S. Pierre, "Dynamic routing algorithms in all-opticalnetworks," in CCECE, 2003.