

Engineering Wireless Mesh Networks: Joint Scheduling, Routing, Power control and Rate Adaptation Networks with Bottleneck Algorithm

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Abstract— the main objective function for our paper is to maximize the minimum throughput among all flows in wireless mesh networks. For this, we first develop new system that add three different modules: first is bottleneck algorithm to avoid dropping the packet during routing, and distributed algorithm to enhance the scheduling of packet via channels with different bandwidth and choose the optimal path according to the highest bandwidth, along with that we add maintenance procedure to manage the power control and rate adaptation in wireless mesh networks.

We also quantify the advantage of multihop over single hop, showing that multi- path optimal routing is not much more efficient than single-path optimal routing and that not all min hop routing are equally efficient.

Index Terms— Wireless Mesh Networks, routing, scheduling, power control, rate adaptation, Bottleneck algorithm, Simplex algorithm.

1 Introduction

The Researchers working in the area of wireless communications heavily rely on simulations to evaluate the performance of proposed algorithms. This is primarily because setting up large scale wireless tested and ensuring repeatability across multiple tested is a difficult task.

Mesh networks are different – full physical layer connectivity is not required. As long as a node is connected to at least one other node in a mesh network, it will have full connectivity to the entire network because each mesh node forwards packets to other nodes in the network as required. Mesh protocols automatically determine the best route through the network and can dynamically reconfigure the network if a link becomes unusable.

2 Related Works

Jain et al. [1] were among the first to formulate a joint routing and scheduling problem for wireless networks valid for all linear objective functions, including maximum-minimum. The framework they proposed is rather comprehensive: it includes both the protocol and the physical interference models, an extension of which is used in this project,

and it can accommodate physical technologies such as multiple radios and non-overlapping channels. One limitation is that power control and rate adaptation are not considered. Jain et al. only provide upper bounds obtained by applying clique feasibility conditions and lower bounds obtained by using subsets of all schedulable link sets.

Zhang et al. [2] apply column generation to solve a similar problem in multi-radio and multi-channel networks.

In [3] using additive interference model does not considering power control and rate adaptation within the work

By using [2], additive interference model with multi power and multi-rate for solving problem [1].

A similar characterization is distinct contribution applied in [5], [2] to construct a new routing metric called interference clique transmission time, though it is not clear how practical such a scheme can be.

There also exists another body of work applying online dynamic control for throughput maximization [6].

in [7] to construct a new routing metric called interference clique transmission time, though it is not clear how practical such a scheme can be.

any attempt at approximating the NP-complete sub problems may drastically reduce the performance [8].

Column generation method has been applied intensively to the cross-layer design of multihop wireless networks.

In[4] making use of a greedy heuristic to obtain suboptimal solutions it does not scale with an increasing problem size and yields to optimal solutions [9].

Jun Luo [10] accommodates physical technologies such as multiple radios and non-overlapping channels.

A new extension in our paper related to use two algorithms with procedure to enhance WMNS Its working mainly depending on bottleneck algorithm.

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Moreover for formulating a joint routing and scheduling problem for wireless networks valid for all linear objective functions, the framework includes both the protocol and the physical interference models.

There have been many attempts to extend this optimization framework and to improve the algorithms that solve it.

The computation of SINR (Signal to Interference and Noise Ratio) should take into account the sum of the strengths of all the interfering signals instead of just the strongest interfering signal [11].

The channel gain model should be comprehensive in that it should include distance based path loss, location dependent shadowing, and velocity dependent fading [11].

3 Network Model and Problem Formulation

- 1- IP Formulation: Will be transformed to ILP Objective Function.
- 2- Objective Function: Minimize the number of used slots

$$\min \sum_{k=1}^K x_k,$$

- Without considering power control

$$PG_{ij} \geq \gamma z_{ijk} \left(\eta + \sum_{\substack{(h,m) \in \mathcal{L}: \\ h \neq i}} PG_{hj} z_{hmk} \right)$$

- Considering power control

$$p_{ijk} G_{ij} \geq \gamma z_{ijk} \left(\eta + \sum_{\substack{(h,m) \in \mathcal{L}: \\ h \neq i}} p_{hmk} G_{hj} \right)$$

- Constraints

- Traffic requirement of each link is fulfill

$$\sum_{k=1}^K z_{ijk} \geq R_{ij} \quad \forall (i, j) \in \mathcal{L}$$

Traffic Requirement

- SINR is enough for transmission

- Without considering Transmission Rate

$$\sum_{k=1}^K z_{ijk} \geq R_{ij} \quad \forall (i, j) \in \mathcal{L}$$

- Considering Transmission Rate

$$\sum_{k=1}^K \sum_{w \in \mathcal{W}} T_w z_{ijkw} \geq R_{ij} \quad \forall (i, j) \in \mathcal{L}$$

4 System Proposed Architecture

In general Column Generation Model, column generation means that not all variables will be considered explicitly; columns will be added to the problem “on the fly”

Pricing problem is ILP(takes long time) In column generation model, instead of solving pricing problem, use greedy algorithm to see if solution can be improved.

The Internet is comprised of packet-processing nodes, called routers, that route packets towards their destinations, and physical links that transport packets from one router to another. Every router is required to perform a forwarding decision on an incoming packet to determine the packet’s next-hop router.

A formal description of our distributed scheduling framework is as follows. It is composed of four phases:

1. Utility exchange. Each node exchanges the utility function of each of its incoming and outgoing links with its neighbors.
2. Initial decision. Each node chooses the link with best utility to be the initial decision of next communication.
3. Initial decision exchange. Nodes with an initial decision of “transmit” – the best link of that node is an outgoing link – broadcast the initial “transmit” decision to all its one-hop neighbor nodes via a control channel.

The control message indicates the IDs of the intended transmitting (origin) and receiving (destination) nodes associated with the initial decision.

4. Final decision., y Each node with an initial decision of “transmit” checks if the desired receiving node is having the same “transmit” initial decision based on the control messages in Phase 3. If so, the node gives up the intended transmission. If not, the node starts transmission in that direction in next slot.

y Each node with an initial decision of “receive” find out the best transmitter based on the control

Messages in Phase 3, and configures its physical layer to be ready to receive data from that direction in the next time slot.

Distributed algorithm the channel assignment problem in the proposed multi-channel wireless mesh network architecture can be divided into two sub problems - (1) neighbor-to-interface binding, and (2) interface-to-channel binding. Neighbor-to-interface binding determines through which interface a node communicates with each of its neighbors. Because the number of interfaces per node is limited, each node typically uses one interface to communicate with multiple of its neighbors. Interface-to-channel binding determines which radio channel a network interface uses. The main constraints that a channel assignment algorithm needs to satisfy are:

1. The number of distinct channels that can be assigned to a wireless mesh network node is limited by the number of NICs on it,
2. Two nodes involved in a virtual link that is expected to carry some traffic should be bound to a common channel,
3. The sum of the expected loads on the links that interfere with one another and that are assigned to the same channel cannot exceed the channel’s raw capacity, and
4. The total number of radio channels is fixed.

At a first glance, this problem appears to be a graph-coloring problem. However, standard graph coloring algorithms cannot really capture the specification and constraints of the channel assignment problem. A node-multi-coloring formulation fails to capture the second constraint where communicating nodes need a common color. On the other hand, an edge-coloring formulation fails to capture the first constraint where no more than (number of NICs per node) colors can

be incident to a node. While a constrained edge-coloring might be able to roughly model the remaining constraints, it is incapable of satisfying the third constraint of limited channel capacity

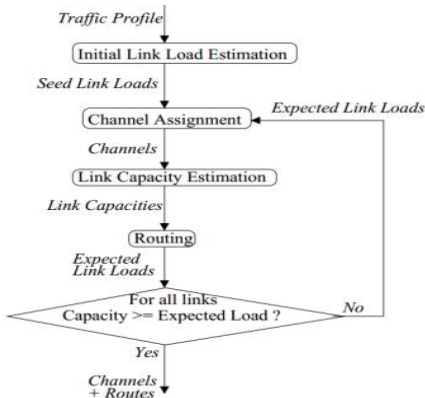


Figure 1: Basic flow chart discussing various aspects of traffic engineering in multi-channel mesh network architecture.

The using of K-Connection traffic Maintenance Procedure:

For maintain N connections the following procedure must be follow by VB node in the network.

Algorithm 3 k=N connection maintenance.

- 1: VB periodically send the number of connection information to all the one hop nodes.
- 2: one hop nodes send their attachment to other VB details to originating VB.
- 3: if $k=7$ (3rd case), VB reserved one R-VB for Upcoming connection request then
- 4: if $k=N$ then (all VB nodes are connected)
- 5: share the connection between one hop R-VB ($k=3$ or 5)
- 6: else ($k>5$, balance routing is not sufficient)
- 7: connect the node to best neighbor
- 8: end if
- 9: end if

The updating of connection balancing is done locally between the VB and other nodes. In this way all local computation supports connection balancing routing in the network.

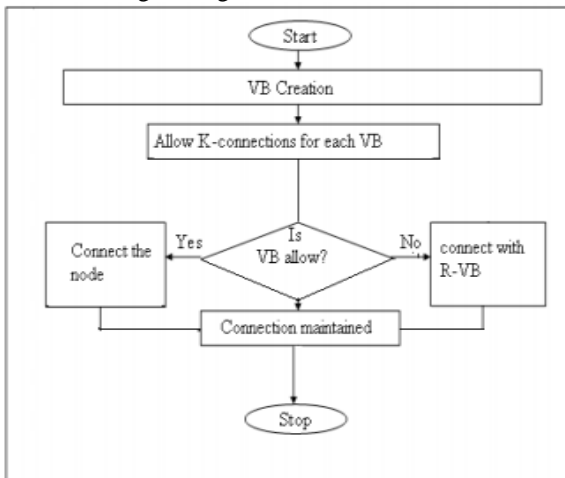


Figure 2: Connections Balancing in Virtual-Backbone (VB)

In both figures drawn below describing of whole proposed system

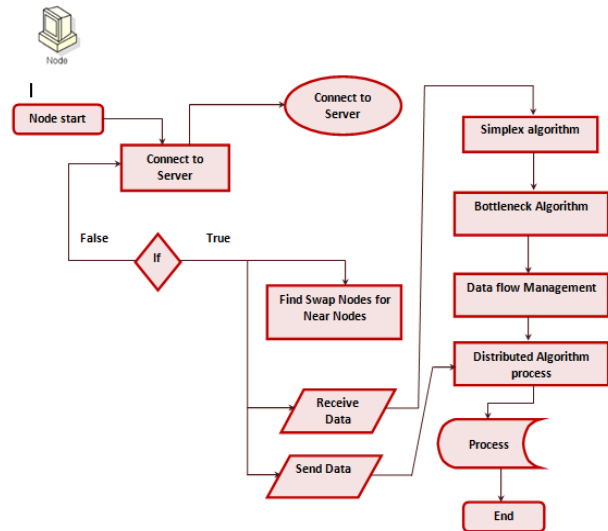


Figure 2: Node side for system proposed

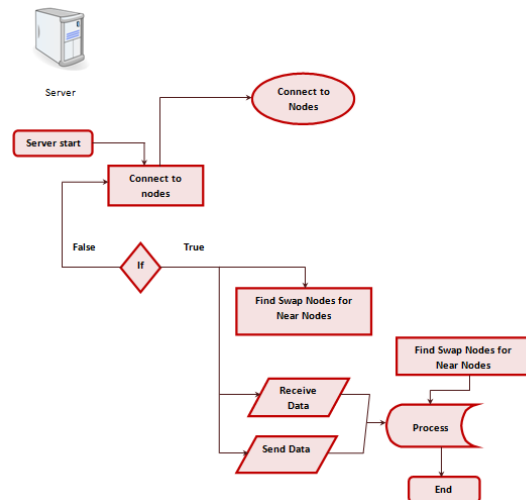


Figure 3: Server side for system proposed server side

In figure 2,3 above describe the way of system working in both node and server side, the main idea is that adding bottle neck algorithm to avoid packet dropping during routing, and managing the packet to high bandwidth channel by using distributed algorithm.

5 Numerical Results

We have chosen to present the results in terms of the average flow rate as opposed to the value of the objective function since the fairness measure does not mean too much practically.

We have to mention that results below did not cover all possible solution rather than take care about specific case in two different ways.

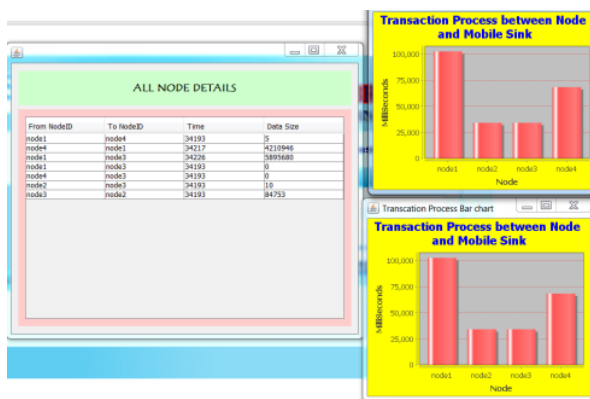


Figure 4: results with using same channel with different size of packet (single hop)

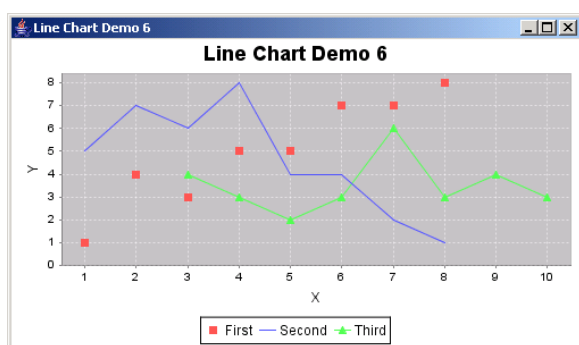


Figure 5: results with using different channel with different size of packet (multiple hops)

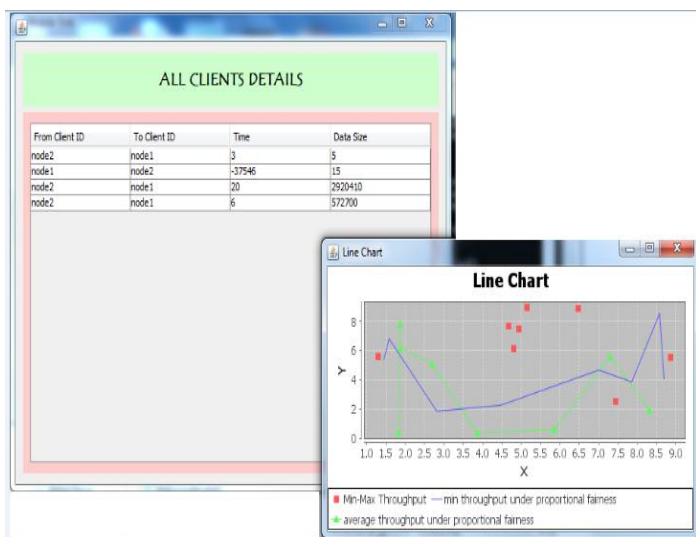


Figure 6 Results with Using Different Channel with Different Size of Packet (multiple-hops).

6 Conclusion

WMNs can be built up based on existing technologies, field trials and experiments with existing WMNs prove that the performance of WMNs is still far below expectations.

As explained throughout this article, there still remain many research problems.

This paper proposes a study of the optimal configurations of fixed mesh networks using conflict free scheduling.

These results are obtained by developing two computational tools to solve exactly the joint routing, scheduling, power control and rate adaptation problem.

The proposed system used first bottleneck algorithm to transfer packet from one client to another, it is used to avoid packet losing during routing operation.

Second distributed algorithm using for joint scheduling packet, the new scheduling algorithm is fully distributed, capable of selecting high utility link combinations to achieve opportunistic gain, and generating reasonably temporal-correlated interference to ensure distributed power control and scheduling performance.

We have to know that is very hard to do routing, scheduling, power and rate control in a real network, because it needs to be node synchronized band done quickly in the presence of changing channel conditions.

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