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Modelling ACI in Multiradio Mesh Networks

Case Study Final Report

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Modelling ACI in Multiradio Mesh Networks

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Abstract
We implement an existing model for the estimation of throughput and goodput between arbitrary pairs of nodes in the presence of interference from other nodes in a wireless mesh network. By using as a guide the existing model of Wireless Interference we can implement faster the Broadcast and Unicast models and even extend it in the future so it takes in account the Multi-Hop Forwarding case and the calculation of packet delay.

1 Introduction

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may but need not connect to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes.

2 Related Work

We set as example different projects in order to study them and understand their point of view on the problem. [5] Focuses on modeling the MAC layer in general for the 802.11 wireless networks, attempts for first time to explain and use in a mathematical model the back-off algorithm and explains the use of Markov Chains to picture the different states of transmitting and receiving nodes. [2] Focuses on modeling single-hop 802.11 Mesh network but with no hidden nodes. So the collisions can only occur when more than one station attempts to use the medium at the same time. [1] Proposes the most accurate mathematical model for Broadcast and Unicast traffic until now and it is the main paper we consider to implement for the calculation of throughput and goodput in an arbitrary pair of nodes, as a future work we will try to extend this model to take in account the forwarding case and the packet delay.

3 Related Work

We have to consider and implement a simple scenario of transmitting nodes and multiple receivers. We examine the cases of broadcast and unicast separately. Values such as Traffic demand and the thresholds (like thermal noise or Radio sensitivity) are fixed and can be changed from the configuration file of the Matlab platform. The model is detailed and has a lot of parameters to achieve the required accuracy. As guide [1] we focus as well in one-hop traffic demands, we do not route the traffic further than one hop.

3.1 Broadcast Traffic

The Broadcast section examines the sender and the receiver side of this scenario. We implement these step by step. The simple case here is calculating the throughput and goodput of the broadcast traffic with saturated demands, in saturated demands we use a fixed value which always is 1 and it means that the back-off algorithm is 0, for the unsaturated demands things are more complex because

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we have to calculate that value for every node separately so we won't exceed the traffic demands of the node. [1] explains the idea behind the calculation of the value and how we construct our iterative algorithm.

Just like the [5] model we construct a discrete Markov Chain to represent the different states of the transmitting nodes, it's presenting incrementally. The purpose of the sender model is to construct the transition Matrix M and to calculate the stationary probability πi for each state. First we construct the sender for saturated demands with variable packet sizes, then we extended for unsaturated demands with variable packet sizes. The transition matrix of Markov chain is based on 802.11 DCF and we use it to compute the stationary probability of each state. With the stationary probability we calculate the throughput for every node.

The goal of the receiver model is to calculate the goodput, meaning how much of the actual traffic is being received successfully. Thus, here, the calculation of packet losses is important in order to calculate the throughput and the goodput. We estimate the losses in the form of probabilities. We have two kind of losses, slot level losses (the fraction of time slots in which loss occurs) and packet level losses that we have to take in consideration, that's the main challenge for the receiver model. [1] in the section 4.2 explains the way how the losses calculated to give realistic results. We have to note that the graph library we use for the synchronization graph (there are synchronous and asynchronous slot level loss rates), so that we can calculate packet level losses are taken from the site:

http://www.ams.jhu.edu/~ers/matgraph

3.2 Unicast Traffic

Now, we extend the Broadcast Traffic model to handle Unicast Traffic. There are two major differences between Broadcast and Unicast. On the sender side we have a different transition matrix M due to ACK, Contention Window, Overhead and exponential Back-off. On the receiver side we have additional loss probabilities due to ACKs colliding with each other and with data.

While computing the Contention Window for the sender we notice that it may transmit to more than one receiver, each with different loss rate. We calculate a weighted average Contention Window and we approximate the weight (Gmn) to be the expected number of transmissions for each data packet sent from sender m to receiver n. Here as well, first we calculated for unicast saturated demands with a small adjustment and then we extend for unsaturated demands. The trick here is to be able to calculate contention window and overhead we must know the packet loss for a pair of nodes (sender, receiver), it will be explained to the receiver model how we put it together.

The major difference on the receiver side for the Unicast Traffic is that we split the packet loss rate (L_{mn}) into three components:

1) L_{rssmn} losses due to low Received Signal Strength (RSS)
2) L_{synmn} losses due to collision of synchronized transmissions and
3) L_{asynmn} losses due to collision of asynchronous transmissions.

The key extensions that we need to make are:

1) Extend L_{rssmn} to include RSS losses for both data and ACK packets and
2) Extend $l_{mn}|S$ to include SINR induced slot-level loss due to collision between ACK/data, data/ACK, ACK/ACK, in addition to data/data.

Unlike the broadcast model the unicast model has tight coupling between the sender and the receiver model, as we mention the contention window and the overhead need the packet loss rates, so we create an iteration framework to refine our model and take more accurate results.

4 Proposed Extensions

Since the implementation of Broadcast and Unicast Traffic we were assigned to extend the current model to consider the following:

- Multi-Hop Forwarding case
- Packet Delay

4.1 Multihop Forwarding

Until now there is not a model that can properly calculate the throughput or goodput in a multi-hop mesh network, to succeed that we have to take as a consideration multiple factors, such as the problem of the same time transmission from node 0 to 1 and 1 to 2 in a three node example. For a future work is to find and calculate with the prior knowledge of this paper in a similar pattern and use of the existing program.

4.2 Packet Delay Calculation

The end – to – end packet delay in a Wireless Mesh Network is defined as the sum of the queuing and transmission delays at the intermediate mesh routers. In order to evaluate the end – to – end delay we first prove the following two lemmas:

1) We find the average number of active interfering neighbors of a mesh router.
2) We find the number of times the back-off timer of a router is frozen during a transmission epoch.

5 Implementation and Evaluation

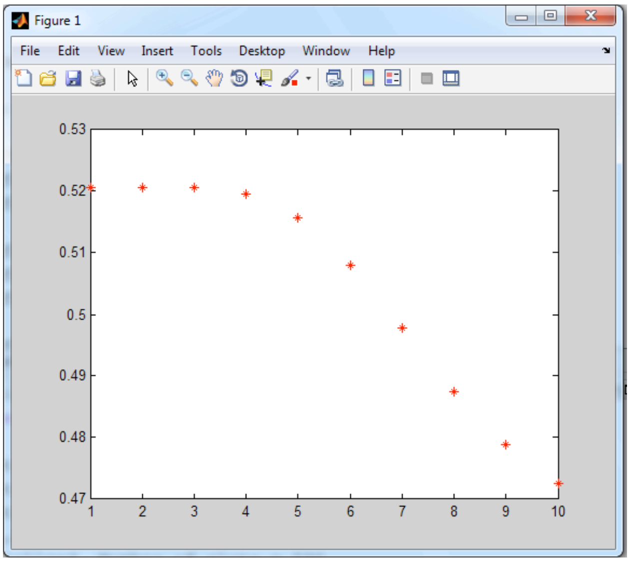
The implementation is being done using the platform of Matlab. We start with the implementation of the Broadcast traffic (for the sender and receiver model). The major parts of the sender model are the calculation of the steady state and Transition Matrix M. In the sender model we calculate with separate functions the transition matrix and the transition probabilities for state. Most important part is the calculation of clear probability which it's used to calculate the transition probability that one node is entering the transmission mode, we have to take as consideration the total interference and the CCA threshold β, because we are talking about random variables we reduce them to lognormal variables, the lognormal distribution gives better results for the measured RSSI, according to the authors of [1]. The receiver model the most important part of the calculation is the estimation of loss probabilities due to collisions. First we have to calculate the slot level probabilities where we calculated the same way as the clear probability, but we have different threshold. Then we compute the packet loss rates where it's divided to synchronous and asynchronous packet loss. We use graphs to compute the set of all states whose synchronization graph has at least one edge involving the current sender.

The implementation of the Unicast traffic followed a similar pattern. Essentially it is like the Broadcast traffic but extended to fit the major differences between those two. The extension for the sender model that is required is the different context of contention window CW, the overhead OH and the probability Q for unsaturated demands (we use a slightly different Q for the broadcast as well). The extension for the receiver model is that we take in account different packet collision cases. Such cases are:

- Data loss due to collision with other data
- Data loss due to collision with other ACKs and data
- ACK loss due to collision with other ACKs and data

The Broadcast traffic doesn’t take into account the acknowledgments (ACKs), because there is no response from the receivers for the successful packet reception, but we implement this for the Unicast traffic. As we mention before the important part for the unicast model is to converge, because packet loss it is needed in the sender model before we calculated at the receiver. We succeeded it with a function that sets the packet losses as 0 for the first time of use and after each iteration we save the new packet losses to the configuration file and we use them at the new iteration, every time we check to see if we have conversion (Q is calculated in similar way in the same function).

For a simple case we construct some plots, where we calculate the throughput and goodput to see some results and evaluate the program and our work so far, we must take as consideration that the program has some bugs due to the complexity of the mathematics. The scenario has three nodes where the middle node has zero demand and we move it by 1 meter each time, it started closer to the first node and after each iteration it goes closer to the third. We have unsaturated demands and the nodes 0 and 2 are transmitting where the node 1 is only a receiver.



As we can see from the figure above, the goodput from node 0 to 1, when the node 1 is closer to node 0 has its highest goodput, but when it moves away from node 0, the goodput starts to decrease.

References

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