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Joint Design in Wireless Mesh Network

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Abstract: ***Wireless multihop mesh networks are an attractive solution to offer good throughput, energy, and coverage trade-offs. Joint design have been proposed to improve the adaptability and performance of multihop mesh networks. Joint design provides an opportunity to optimize performance by jointly tuning parameters at the different layers. The performance of the network depends on routing, medium access, and physical-layer parameters congestion control and on their interactions. An efficient physical interference model is considered for cross layer design of a fixed random access based wireless multihop network. CSMA/CA medium access control (MAC) protocol for link-layer operation is considered. Then a joint routing, medium access, and transmission range optimization problem is considered to determine the optimal configuration of the routing, access probability, and transmission range parameters in a CSMA/CA system . This study helps us to provide insights on the interaction of various network layer parameters and to further improve the network performance.***

Keywords: Cross-layer, medium access control, routing, throughput, reliability

1. Introduction

The success of communication networks has been a result of adopting layered architecture. In this architecture, its design and implementation are divided into simpler modules then they are separately designed , implemented and then interconnected. A typical protocol stack has five layers such as application, transport (TCP), network (IP), data link (include MAC) and physical layer. Each layer holds a subset of decision variables and provides well-defined services to the layer above by abstracting away the complexities in the lower layer. But this layered architecture is not successful in wireless networks, so in order to increase the performance and reliability we go for a cross layer design. By cross layer design we mean that jointly tuning the parameters of different layers. Since the layered architecture addresses only the abstract or higher level aspects of the whole protocol stack, to improve the performance and reliability we must have the knowledge of interaction across various layers. Configuration of wireless link based on random access mechanism is more difficult than a default configuration. While one would expect that joint design provides a better performance than the default configuration.

In wireless networks the main reason for packet losses are multipath signal fading and the interference from neighbouring transmissions. As a result we must use a proper interference model during the configuration of the wireless network. Here we consider an interference model which is based on signal to interference plus noise ratio. In the proposed system CSMA/CA medium access which having high contention characteristics is considered. CSMA/CA based system have the advantage of avoiding contention among various simultaneously transmitting nodes.

In the proposed system main objective is to improve the overall network performance and the reliability. Here joint tuning of physical, medium access, routing and congestion parameters are considered. By doing so reliability and performance is increased. In the joint design different parameters are extracted from each layer and an optimization procedure is done with the aid of an iterative optimal search algorithm. Thus this provide insights on : 1) Interaction of various parameters in each layer. 2) Performance gain obtained by a joint design

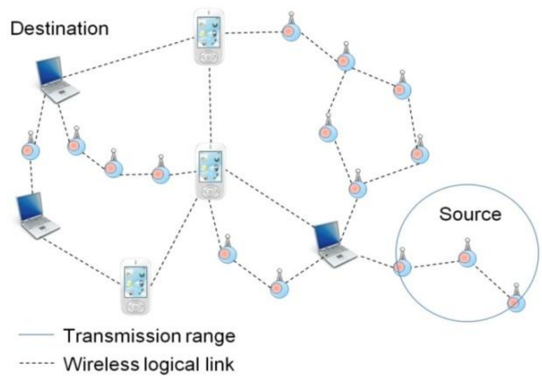

Figure 1: System architecture of a simple wireless mesh network

2. Problem Formulation

Here, we consider the joint design utilizing the various parameters such as routing, access probability, transmission range, congestion parameters for CSMA/CA based wireless network.

In the proposed system we consider a constant bit rate wireless mesh network, which is a multihop access network containing a gateway node connected to the internet and several other nodes. In this system we are considering the different parameters from different layers for the optimization procedure. Since we are considering wireless medium the system is evaluated under a physical interference model. For that here we assume that the channel gain between the transmitter and receiver are time in variant. It is said that a directed link exist between two nodes if it is possible to communicate in the absence of interference at least with minimum transmission rate, i.e. the SNR of the link is greater than or equal to $\gamma(r_{\min})$

$$\frac{GP_t}{N_0} \geq \gamma(r_{\min}) \quad (1)$$

where G is the channel gain between two nodes, P_t is the transmitted power, N_0 is the noise power. Thus generally a packet is successfully delivered if (1) is satisfied. Another physical layer parameter considering here is the transmission range, which is analyzed for different ranges and accordingly the transmission power is chosen.

We know that the wireless networks are unreliable and depends on random access techniques to access the channel. Mesh network based on CSMA/CA medium access is considered. Here the nodes can access the channel probabilistically, which denote the probability(π_n) that the node n tries to access the channel. For medium access, the node generates the binary values 1& 0 corresponding to highest and lowest probability. If the result is 1 it performs routing to transmit the packet otherwise it keeps silent. The value of access probability depends on traffic in transmitting nodes and also the traffic in the other nodes. Thus a good approximation of access probability is given by

$$\pi_n = \frac{y_n}{\sum_{n'} y_{n'}} \pi_0 \quad (2)$$

Where y_n is amount of transmitted by node n and π_0 is an unknown factor and this depends on the network topology. In order to obtain an optimal solution after some test the value of π_0 is taken as 1.The denominator term represents total amount of traffic in the neighboring nodes which have packets to transmit.

In order to achieve process to process communication an efficient routing protocol is needed. Since we are considering multihop mesh network there is a requirement of efficient routing protocol, so we decided to choose AODV protocol. The problem arising here is that if node n tries to access the channel the routing decision is to identify which flow to send. To overcome this constrain we utilize a probabilistic strategy, which is the conditional probability that the node will select a packet to transmit on the particular link. AODV uses on demand approach for finding the routes. The important advantage of this routing protocol is that its connection setup delay is less.

In wireless network nodes can transmit large volume of data towards destination. Here we are concentrating on wireless mesh network, so there may be congestion at the gateway router which may result in the overflow of buffer in the nodes. Due to congestion packets get dropped and there will be wastage of energy which may ultimately result in unreliable data transmission. To mitigate this effect we regulate the reporting rate of various nodes, which is the number of packet send per second. In this system we implement a joint design then finds an optimal solution by utilizing an algorithm knows as iterative optimal search algorithm. Iterative optimal search algorithm is an algorithm that finds a sequence of local maxima by starting with different initial values, at the end of certain amount iteration this gives the best solution.

3. Simulation Result

The platform used here is Network Simulator (NS-2).It predicts the behavior of wireless networks without actually creating one. In the proposed system we use a grid topology as shown in fig:2.The joint design utilize the different parameters from each layer and optimal solution is obtained by utilizing the iterative optimal search algorithm. To determine the optimal solution we use different initial vectors. Here we use 0.5 as the initial vector and number of iteration is 30. The entire system is considered under SNR based physical interference model. The SNR threshold is set as 6.4dB and the noise power taken is -100dBm.

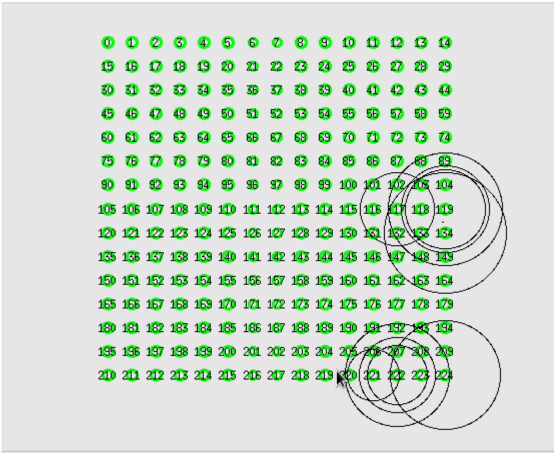

Figure 2: Snapshot of node creation

After node creation the performance metrics of the network is evaluated. The various metrics we considering are packet delivery ratio, packet loss, delay etc. The proposed system is compared with a regular protocol without joint design at different reporting rate. The reporting rate utilized are 10, 20, 30, 40, 50. Fig 2 shows the comparison packet delivery ratio of joint and regular protocol. Packet delivery is the ratio of number of packet received to the total number of packets transmitted. From the simulated result it is found that joint design has good packet delivery ratio compared to the regular protocol.

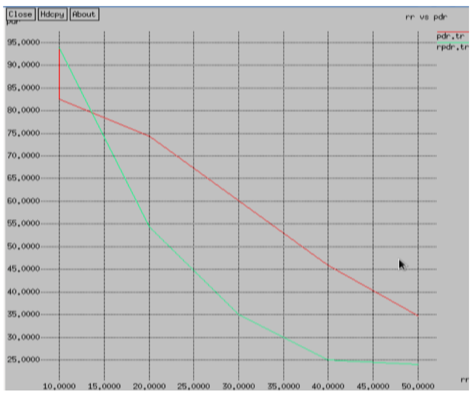

Figure 3: Comparison of PDR of joint and regular protocol

Another parameter considered here is the delay. Delay is the amount of time taken by the packet to reach from source to destination. Delay includes the processing delay, propagation time, queuing time, transmission time. The lower delay of joint protocol is due to the fact that joint design considers the lower aspects of each layer which is as shown in fig 4.

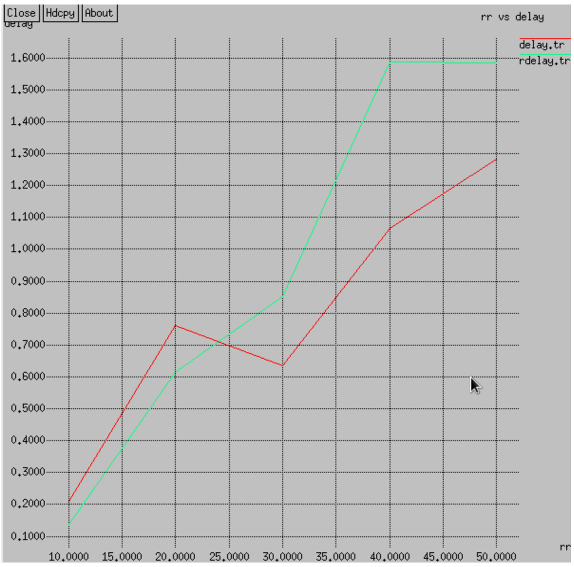

Figure 4: Comparison of delay of joint and regular protocol

Next factor we are considering is packet loss in the entire configuration. It is found that joint protocol has less packet loss compared to regular protocol since we regulate congestion in the network and achieve an efficient protocol design. The graph of Packet loss ratio of both design is as shown in fig:5. Another two factors considered are throughput and control overhead. The of plots of these two factors are shown in fig:6 and fig:7 respectively.

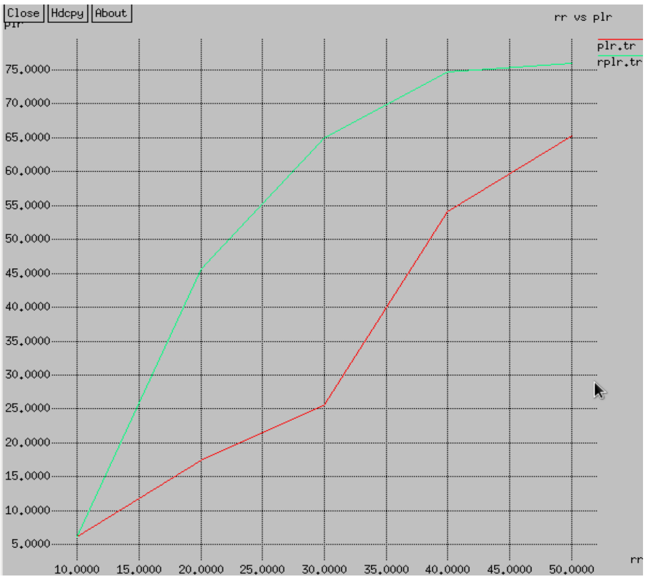

Figure 5: Comparison of packet loss of joint and regular protocol

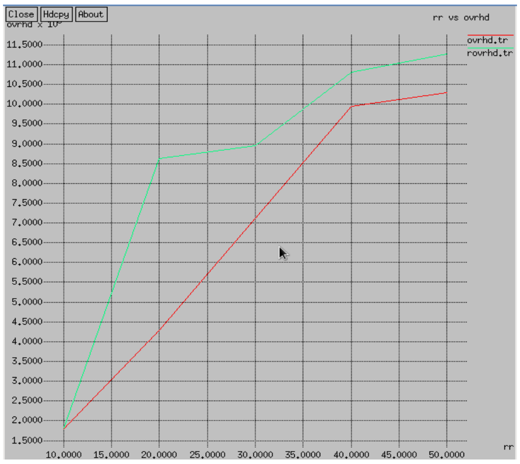

Figure 6: Comparison of control overhead of joint and regular protocol

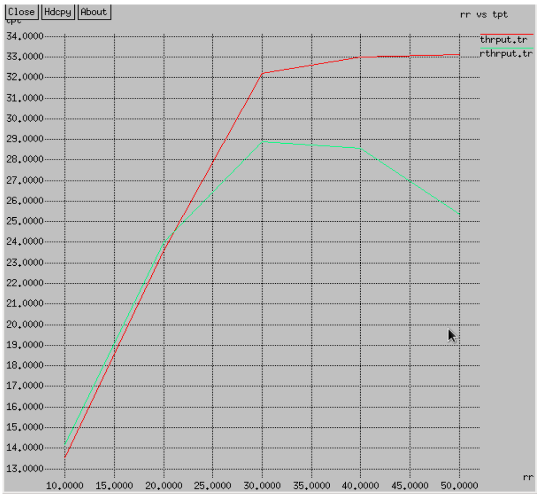

Figure 7: Comparison of throughput of joint and regular protocol

4. Conclusion

In this paper, we have studied the joint configuration of routing, access probability, congestion and transmission range parameters in wireless multihop mesh networks. Here formulated and solved several optimization problems for several wireless mesh network scenarios. The network configuration is evaluated at different reporting rate. And it is found joint configuration provides better performance and reliability compared to a regular protocol.

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Neethu Verjisen received B.Tech degree in electronics and communication engineering from Kerala university, Kerala, India. Currently She is M.Tech student specializing in communication engineering in Mahatma Gandhi university, Kerala. Her topics of interest are wireless communication system and wireless networks.