Scheduling Wireless Ad Hoc Networks in Polynomial Time Using Claw-free Conflict Graphs

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Introduction

We study the scheduling problem in wireless ad hoc networks. In a wireless broadcast medium, networks are usually interference limited and hence, interfering transmissions cannot be done simultaneously. On the other hand, it is necessary to maximize the number of simultaneous transmissions in order to obtain a high throughput in the network. This trade-off enforces us to do scheduling which aims to maximize the number of non-interfering simultaneous transmissions in considered time slot.

Arikan [1] proves that scheduling problem is NP-complete for packet radio networks which is the earliest version of wireless networks. Ephremides and Truong [2] study the problem of scheduling broadcast transmissions in a multihop interference limited wireless network while aiming to optimize throughput. They show that the problem is NP-complete. Sharma et al. [3] also consider the problem of throughput optimal scheduling in wireless networks subject to interference constraints where they assume no two links within K hops can successfully transmit in the same time slot. They conclude that the problem can be solved in polynomial time for K=1 whereas it is NP-hard for K>1. Hajek and Sasaki [4] give polynomial time algorithms for link scheduling in a spread spectrum wireless network where each node is allowed to converse with only one other node at a time. Our modeling of possible transmissions in interference limited network setup and approach using conflict graphs are same with Traskov et al.’s [5] work. Therefore, in our case, scheduling has an NP-hard complexity as in [5] for general conflict graphs.

Theory/Method/Hypothesis

Scheduling can be modeled as maximum weighted independent set (MWIS) problem in the conflict graph. Therefore, scheduling complexity is equivalent to the complexity of finding MWIS in the derived conflict graph of given wireless network as shown by Traskov et al. [5]. Since there are algorithms that can find MWIS in polynomial time in claw-free graphs, we can do polynomial time scheduling if we can get a claw-free conflict graph.

We introduce some families of networks which can be scheduled in polynomial time. We suggest physical modifications in the network setup to make network suitable for polynomial time scheduling. We add new edges to conflict graph in order to break the claws without any intervention to network setup. We introduce a novel heuristic mixed scheduling algorithm based on the distribution of claws in the physical network.

Results

To evaluate the performance of our claw breaking strategy, we conduct simulations on randomly located 15 transceivers in a 2-D coordinate system with an area of 10x10. Simulation results give us the weights of MWIS. Since, weight of the resulting independent set and network throughput are proportional, we consider MWIS weight as maximum network throughput in figures as seen in y-axis labels. We compare the performance of claw breaking with the optimal performance of the network. Results of claw breaking strategy can be seen for 15 transceivers and for full duplex and time division duplex transceivers in top two figures, respectively. For both cases, our solution performs nearly optimal. Two bottom figures show the number of edges introduced to break all claws in the conflict graph of the network.

Conclusion/Perspectives

We conduct simulations on the suboptimality of claw breaking strategy. We observe that this strategy works nearly optimal for both time division duplex and full duplex transceivers and for various number of transceivers. The only limitation is the need for directed antennas. Because, with omnidirectional antennas, the number of claws in the conflict graph is very high and shows a very rapid increase with the transmission range of transceivers. Deployment of omnidirectional antennas almost always increases the number of neighbors a transceiver has, therefore increasing the tendency of a network to break the rule on the limit of maximum number of neighbors. Thus, deployment of directed antennas is crucial for both construction of the conflict graph and for the better performance of claw breaking strategy. As a future work, energy efficiency of the transmissions done in network can be considered using Multi-Armed Bandit approach.

References


Acknowledgments

I would like to thank Prof. Muriel Medard for accepting me to do my master’s thesis in her Network Coding and Reliable Communications Group at MIT and also for her always positive moral and material support.