Chapter 13

COMMUNICATION CONSTRAINTS AND AD HOC SCHEDULING

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Abstract

Communication constraints, in the context of scheduling in a wireless ad hoc (multi-hop) network, are a set of rules defining permissible concurrent transmissions. These rules may be imposed either by technological limitations of the transceiver, or by the operational mode of the network. This paper considers 24 distinct communication constraint sets (CCS) by comparing the average cardinality of a maximal schedule under each CCS using a greedy edge selection heuristic. The average cardinality as a function of the network size is studied via Monte Carlo simulation. The simulation results are useful for network and transceiver designers by identifying the sensitivity of scheduling performance to the CCS. In particular, the results illuminate that the performance gain obtainable by removing each constraint is highly dependent upon the overall CCS.

Keywords: Ad hoc networks; scheduling; communication constraints; combinatorial optimization.

1. Introduction

Communication constraints, in the context of scheduling in a wireless ad hoc (multi-hop) network, are a set of rules defining permissible concurrent transmissions. These rules may be imposed either by technological limitations of the transceiver, or by the operational mode of the network. Several of these constraints are listed in Table 13.1. As shown there, none of the constraints is by nature fundamental. Although technologies exist to circumvent

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each of these constraints, they are overcome at a cost, possibly measured in terms of additional hardware requirements (and the associated higher monetary cost), processing time (e.g., of complex algorithms), or performance (e.g., reduced transmission rate). In practical network deployments these costs may be prohibitive, and the designers may elect to deploy networks that must operate subject to some of these constraints. Given the breadth of possible ad hoc network designs, it is not surprising that researchers have employed a wide variety of communication constraint sets (CCSs) in their mathematical models. A thorough review of the scheduling literature confirms that there has been no systematic study of the algorithmic and performance impacts of these models. The algorithmic impact of a CCS relates to the computational complexity of scheduling under that CCS, and the viability of distributed polynomial time approximation algorithms (for NP problems). The performance impact of a CCS relates to bounds on, say, the cardinality of an optimal schedule achievable under the CCS, and the performance improvement obtained by each constraint’s removal. A systematic constraint impact study is a vital next step for next generation ad hoc transceiver and protocol design: it will illuminate fundamental design limitations and suggest areas for design improvement.

This paper is a first step towards a systematic study of the various CCSs. We restrict our attention to unidirectional point to point communication, leaving bidirectional and broadcast communication for future work. The ideal performance metric for this study is the Monte Carlo average cardinality of a maximum schedule under each CCS; unfortunately finding the maximum schedule is NP-Complete for many CCSs, and thus computationally infeasible for even small to moderate sized networks. Instead, our performance metric is the Monte Carlo average cardinality of a maximal schedule under each CCS, using a greedy heuristic edge selection rule. In particular, the edges in the communication graph (indicating potential communication) are sorted from strongest to weakest (i.e., shortest to longest), and an edge is added if the resulting schedule satisfies each constraint in the CCS. This heuristic is somewhat arbitrary (other greedy approaches may work as well or better), but is certainly a reasonable low complexity approximation of the maximum schedule. A further justification of the greedy heuristic is that practical low-complexity schedules in real networks are likely to employ greedy (distributed) heuristics to find (locally) maximal schedules, rather than seek optimal schedules.

The average cardinality of a maximal schedule is studied as a function of the network size. The simulation results identify the sensitivity of the schedule

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1 A schedule is maximum if its cardinality is at least as large as that of all other feasible schedules. A schedule is maximal if adding any additional transmissions will violate one or more of the constraints. Finding maximum schedules often requires searching over the entire space of possible schedules, while maximal schedules are easily found by greedy algorithms (like the sorting heuristic employed here).