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Analysis of Bandwidth Allocation Algorithms for Bluetooth Wireless Personal Area Networks

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***Abstract*— A major issue in the operation of ad hoc networks is the design of mechanisms for sharing the common spectrum among links in the same geographic area. Bandwidth allocation, to optimize the performance of networks in which each station can converse with at most a single neighbor at a time, has been recently studied in the context of Bluetooth networks. There, centralized and distributed, capacity assignment heuristics were developed, with applicability to a variety of ad hoc networks. In this paper we present our analytic results regarding these heuristics. Specifically, we show that they are β-approximation ($\beta < 2$) algorithms. Moreover, we show that even though the distributed and centralized algorithms allocate capacity in a different manner, both algorithms converge to the same results. Finally, we present numerical results that demonstrate the performance of the algorithms.**

***Index Terms*— Bluetooth, Scatternet, Bandwidth allocation, Capacity assignment, Scheduling, Approximation algorithms, Graph theory.**

I. Introduction

In the last four decades, much attention has been given to the research and development of bandwidth allocation and scheduling schemes for wired and wireless networks [4],[23],[26]. Due to various reasons (e.g. high mobility, distributed operation, unique MAC layer), the bandwidth allocation problem in wireless ad hoc networks significantly differs from the problem in static communication networks. For instance, one of the major problems in the design and operation of ad hoc networks is sharing the common spectrum among links in the same geographic area. A unified framework for dealing with many variations of this problem has been presented in [23]. In this paper, we focus on bandwidth allocation in networks in which *each station can converse with at most a single neighbor at a time* [13],[23]. This problem has been recently studied mainly in the context of Bluetooth Personal Area Networks [2],[18],[25],[27],[30],[31].

Bluetooth enables portable mobile devices to connect and communicate wirelessly via short-range ad-hoc networks [6],[7],[17]. The basic Bluetooth network topology (referred to as a *piconet*) is a collection of slave devices operating together with one master. A multihop adhoc network of piconets in which some of the devices are present in more than one piconet is referred to as a *scatternet* (see for example Fig. 1). Efficient scatternet operation requires determining the link capacities that should be allocated in each piconet, such that the network performance is optimized. We envision that in the future, capacity assignment protocols will be invoked between scatternet formation and scatternet scheduling protocols (see Section II-B), and will be required in order to improve the utilization of the scatternet bandwidth.

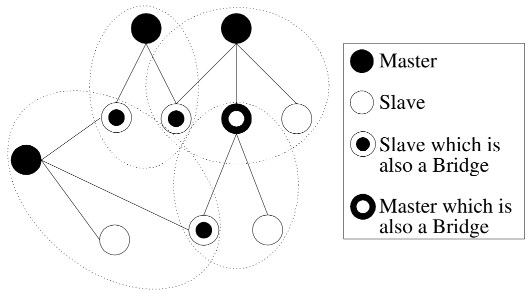

Fig. 1. An example of a Bluetooth scatternet composed of 4 piconets.

Unlike the issues of scheduling and topology construction, which have received considerable attention, the issue of capacity assignment in scatternets has not been thoroughly investigated. Thus, in [30] and [31] an analytical model for the capacity assignment problem has been presented, and distributed as well as centralized heuristics for its solution have been developed. The analysis there is based on a static model with stationary flows and unchanging topology. Accordingly, the formulation of the problem is based on the assumption that the flow rates are given by higher layer protocols based on the traffic statistics. We believe that the algorithms described in [30] and [31] are expected to provide insight into the development of good capacity allocation schemes. As argued by Sarkar and Tassiulas [25],[27], although those algorithms have been developed in the context of Bluetooth scatternets, they can be applied to any ad hoc network in which a