Distributed Saturation Degree Methods for Code Assignment in Multihop Radio Networks

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Abstract

We present a new distributed algorithm for code assignment in a multihop radio network. The algorithm is based on the Saturation-Degree coloring scheme proposed in [1], which has proved better than earlier attempts at solving the problem. A crucial parameter of the proposed algorithm is the depth of the neighborhood that must be considered when a local decision must be taken. By tuning this parameter one can obtain a tradeoff between the quality of the solution and the number of parallel passes and exchanged messages.

We analyze the results of our simulation programs where the proposed algorithm is compared with its sequential version and with competitive schemes proposed in the literature.

1 The saturation degree heuristic

The basic design principles of the Saturation Degree coloring heuristic proposed in [4] is that the first nodes to be colored are those that have more colors already assigned to nodes in the neighborhood. The motivation is that these nodes have a more constrained choice and therefore a higher risk that at a certain moment, having all colors been assigned to neighbors, a new color needs to be introduced, and a higher overall number of different colors will be necessary in future steps. The heuristic is used in [4] to choose the next branching node in the branch & bound algorithm DSATUR. Korman [10], and later Ramanathan [14], recommended choosing a node with highest degree in the uncolored subgraph (Progressive Minimum Neighborhood First, PMNF) and Kubale and Jackowski [9] validate the choice in their experiments.

2 The distributed algorithm

So far, the Saturation Degree heuristic has been implemented as a sequential algorithm [1]. In fact, at each step only the node having the globally maximum number of channels blocked is allowed to proceed; if we want to introduce a distributed technique based on Saturation Degree we need to cope with the fact that the knowledge of a node does not extend to the whole network, but is limited to the status of its neighbors, eventually up to a certain depth.

In order to be enabled to choose its own color, a node must ensure that it satisfies the saturation degree condition up to a certain depth of neighbors. We refer to the maximum neighbor depth as the "depth" of the distributed algorithm, and we identify it by the positive integer parameter ρ.

When a node considers itself a candidate for coloring, it sends out a message to ask its neighbors for permission. Every neighbor, up to depth ρ, answers by communicating its own saturation degree and other tie-breaking data. If the candidate node has the highest saturation degree (or, in case of tie, a higher order with respect to its direct contendants), it colors itself, based on the fresh information received by its neighbors. Then it communicates its new status to its neighbors up to depth ρ, which consequently update their saturation degree. If a node increases its saturation degree over the highest known value, it considers itself a new candidate for coloring and starts gathering information from its neighbors.

At the beginning of the coloring procedure, every node considers itself a candidate for coloring.

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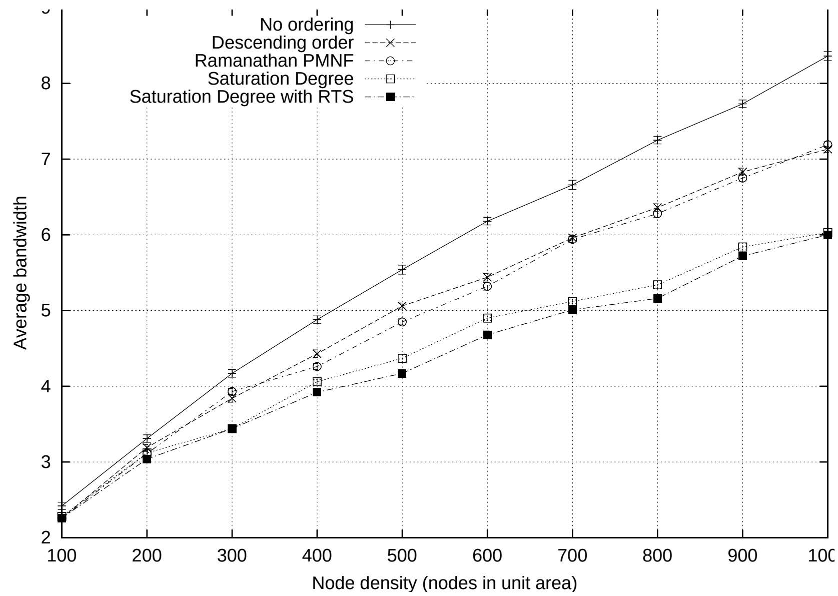

Figure 1: Comparison among sequential algorithms

The performance of the distributed saturation-degree heuristic is expected to improve as ρ grows. In fact, if the graph is fully connected the distributed algorithm is almost equivalent to its sequential version when ρ is large enough.

3 Experimental results

Simulations were executed by uniformly scattering random points on a unit square. Each point, representing a mobile host, is able to broadcast a radio signal within a circle of radius 0.05 units. As all hosts have the same power, the Euclidean communication graph (a vertex for every host, a link between points if they are nearer than 0.05 units) is undirected.

The problem taken into account in the experimental tests is the hidden interference problem, where two nodes are connected by an arc if and only if they are second-order neighbors in the primary Euclidean graph (i.e. iff they are not primary neighbors and have a common primary neighbor). Evidence is given in [1] that, of the three possible problems (primary interference, hidden interference or both), the hidden interference is the most difficult to treat.

In figure 1 we show a comparison among some sequential greedy techniques: unordered and descending order [3], PMNF (see Section 1) [14], the sequential Saturation Degree heuristic described in Section 1 [1] and the same heuristic followed by two iterations of Reactive Tabu Search [2]. The saturation degree heuristic (either in its pure and postprocessed form) clearly outperforms all other considered algorithms. This obvious advantage motivated our choice of the algorithm to distribute.

The results shown in figure 2 show that, although the distributed version of the algorithm that considers only first neighbors deteriorates the algorithm performance, a variation where neighbors up to a given distance are considered before taking a decision achieves results that are comparable to those of other preprocessed greedy techniques. Moreover, a tradeoff between parallelism and performance can be obtained by tuning the parameter ρ, which indicates how "deep" a message must travel in the neighborhood. A good performance is obtained by just setting ρ to 3.

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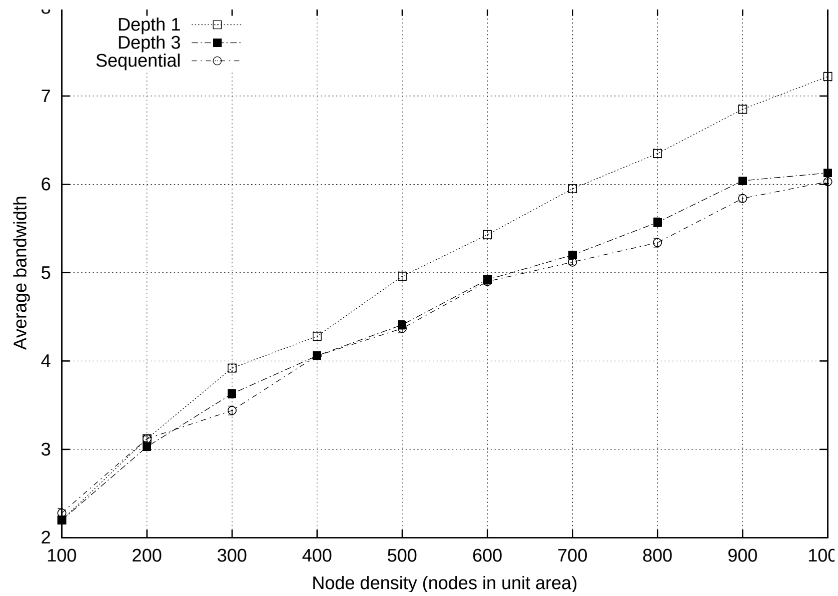

Figure 2: Comparison among different depths of the distributed algorithm

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