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Distributive routing and congestion control in wireless multihop ad hoc communication networks

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Abstract

Due to their inherent complexity, engineered wireless multihop ad hoc communication networks represent a technological challenge. Having no mastering infrastructure the nodes have to selforganize themselves in such a way that for example network connectivity, good data traffic performance and robustness are guaranteed. In this contribution the focus is on routing and congestion control. First, random data traffic along shortest path routes is studied by simulations as well as theoretical modeling. Measures of congestion like end-to-end time delay and relaxation times are given. A scaling law of the average time delay with respect to network size is revealed and found to depend on the underlying network topology. In the second step, a distributive routing and congestion control is proposed. Each node locally propagates its routing cost estimates and information about its congestion state to its neighbors, which then update their respective cost estimates. This allows for a flexible adaptation of end-to-end routes to the overall congestion

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state of the network. Compared to shortest-path routing, the critical network load is significantly increased.

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1. Introduction

In two previous Papers [1,2] we have already discussed the so-called wireless multihop ad hoc networks. They represent an engineered communication network, which reveals many facets of very intriguing and complex behavior. In this respect they fit nicely into the cross-disciplinary realm of the Statistical Physics of complex networks [3–5], which has already opened its doors for other communication networks like the Internet, but also for biological and social networks.

Wireless multihop ad hoc networks represent an infrastructureless peer-to-peer generalization of todays wireless cellular phone networks. Instead of being slaved to a central control authority, each node not only sends or receives packets, but also forwards them for others. Consequently, communication packets hop via inbetween ad hoc nodes to connect the initial sender to the final recipient. A lot of coordination amongst the nodes is needed for the overall network to perform well. They have to ensure network connectivity, good data-traffic performance and robustness against various forms of perturbations, just to name but the most important issues. Because of this intrinsic coordination, wireless multihop ad hoc networks represent an excellent example of what is called a selforganizing network. However, their biggest challenge is yet to come, how to get selforganization to work.

The connectivity issue has already been discussed quite extensively [1,6–9], also addressing interference effects [10,11]. In one form or the other all these efforts relate to continuum percolation [12–14]. An interesting distributive scheme has been put forward in Ref. [1], which turned out to be amazingly robust, guaranteeing strong network connectivity almost surely; we will briefly touch upon this scheme again in Section 2.1. The robustness issue with respect to selfish users has received inspirations from the biological immune system and distributive algorithmic suggestions have been put forward [15].

As to data-traffic performance, estimates on the throughput, i.e., the capacity of how much end-to-end traffic the network is able to handle without overloading, have been given. In Ref. [16] a rigorous upper bound has been derived to scale with the square root of the network size. Refined estimates have been given in [2], revealing that the scalability of the throughput depends on the underlying network structure. Besides several other idealistic assumptions, these estimates have employed shortest-path routing. Although several proactive and reactive routing schemes have already been discussed