Poster: On Capacity Maximization in Wireless Relay Networks

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1. INTRODUCTION

A wireless sensor network (WSN) [1] consists of small autonomous low-cost low-power devices that perform monitoring tasks. Often, sensors are required to monitor a large area and for that reason are sparsely deployed. As a result, direct *sensor-to-sensor* or *sensor-to-base-station* communication may not be possible due to high transmission energy costs over long distances. Various methods, such as *directional antennas* and *cooperative communication*, were developed to overcome the challenge of long-distance transmissions in WSNs. A different approach for long-distance transmissions in a sparsely deployed WSN is to use *relay nodes*, which is a lightweight (hardware- and protocol-wise) alternative to the other techniques. In this paper, we address bottleneck link capacity maximization in a multi-hop WSN under the Gaussian channel model through relay placement and power allocation schemes.

2. WIRELESS NETWORK MODEL

A power assignment p sets the transmission power of wireless devices (nodes). A wireless link (u, v) is feasible if $p(u) \geq d(u, v)^{\alpha}$, where $d(u, v)$ is the Euclidean distance between u and v and α is the *path-loss exponent* [3]. According to the Gaussian channel model, the rate at which data can be sent over a wireless link (u, v) is a function of the Signal to Interference plus Noise Ratio (SINR) of the link [2]. We assume omnidirectional antennas, so that two simultaneous transmissions are mutually interfering. For a power assignment p, the capacity (in bps) of a directed communication link $(u, v) \in E_p$ is defined as $B \log(1 + SINR)$, where B is the channel bandwidth. The SINR of (u, v) under p is the ratio between the signal strength (numerator) and the overall interference (denominator): $SINR = \frac{p(u)/d(u,v)^{\alpha}}{N_0 + \sum_{w \in V \setminus \{u,v\}} p(w)/d(w,v)^{\alpha}}$, where N_0 is the ambient noise.

3. OUR CONTRIBUTION

We consider a *highway network model* with two sensors, $s = v_1$ and $t = v_{n+1}$. The relay nodes $v_2, \ldots, v_n$ are positioned on a line segment between the sensors (Figure 1). The objective is to induce a maximum bottleneck capacity directed communication backbone to propagate data from the source s to the destination t. We explore three critical aspects of the capacity maximization problem:

Dynamic layout: *Where should the relay nodes be placed?* This is one of the first challenges faced by the network designer when a WSN is initially deployed. We prove that if a minimum power budget is utilized then a feasible bottleneck SINR is upper bounded by 1. In addition, we claim that by equally spacing the relay nodes we can achieve a bottleneck SINR of $3/(\pi^2 - 3)$.

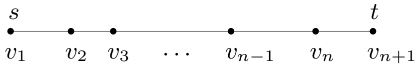

Figure 1: The highway model

Selective activation: *Given a fixed layout of relay nodes, which nodes should be used for a transmission?* It might be impossible to control the deployment of relay nodes with high precision. Moreover, some of the relays might shift from their initial positions. By selectively activating only a subset of relay nodes, we can avoid unfortunate configurations with negligible network capacity. We argue that it is possible to achieve a bottleneck SINR of $2/3\pi^2$ through balanced activation of relays. Then, we propose an additional optimization technique that eliminates potentially bad links in a greedy fashion.

Power allocation: *Given a fixed relay backbone, what is the best transmission power allocation?* Varying the transmission power assignment might be the only tool at the network designer's disposal to increase the bottleneck capacity. The layout of the relay nodes is fixed and the unicast session from s to t is carried out along the path $\langle v_1, v_2, \ldots, v_{n+1} \rangle$. We derive an upper bound of 4 for the feasible bottleneck SINR for any power assignment. Then, we show how to compute the *optimal* power assignment. Finally, we develop an iterative approach that can be used as a more practical alternative to the optimal computation.

4. FUTURE WORK

A natural extension to this work would be to study the general two-dimensional scenario. In fact, the derived upper bounds can be easily carried into the general case. However, whether an optimal solution exists in the two-dimensional case, remains an open question.

5. REFERENCES

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