Energy Savings in Wireless Networks through Network Coding

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1 Introduction

Emerging applications in wireless networks require more and more resources. One of the most important limitations is formed by battery life. Since battery technology is not keeping up with the increasing demand for resources, it is imperative that more efficient use is made of the available energy. Previous work on minimizing energy consumption in networks has focussed on, *e.g.*, minimum cost routing, power control algorithms and cross-layer protocol design. However, exiting new opportunities arise from the advent of network coding.

In a typical communication network sources and receivers can not communicate directly, other nodes in the network are therefore required to setup communication links. In state of the art networks this task is performed by routers which operate by forwarding incoming packets to other parts of the network. An important observation is that simply forwarding packets is not the only operation possible at these intermediate nodes. Network coding [1] arose in the information theory community around 2000 by demonstrating the potential benefit of allowing nodes to perform operations on incoming packets before retransmitting them. In what is by now its most popular form, network coding allows operations over a finite field, e.g. taking the bitwise xor of two packets. Network coding no longer keeps data from different connections independent, but mixes them.

2 Aim of the Research

The aim of our research is to get an understanding of the potential of network coding for reducing the energy consumption in wireless networks. We compare, for example, the amount of energy required if network coding is used to the energy consumption of plain routing. In addition, we consider the tradeoff between the energy consumption reduction offered by network coding with other performance measures like throughput and delay.

The stochastic processes that arise from wireless networks employing network coding are different from traditional queueing networks. In order to answer the

above questions, we need to develop an understanding of the properties of these processes.

3   Results

One of our contributions is the result that for networks with nodes positioned in a plane, network coding potentially requires as little as 25% of the energy required for routing. This improves upon previous known bounds on this percentage. The key ingredient to this result is that the broadcast nature of the wireless medium ensures that all neighbours of a transmitting node can receive a message. By properly encoding each transmission we can ensure that each transmission is useful for multiple connections in the network.

In order to achieve the abovementioned energy reduction, each node needs, at all times, packets from several connections. If, however, we take the stochastic arrival of packets into account, we see that this can not always be the case. In another line of research, we take the stochastic arrival of packets into account and model a network as a continuous-time Markov process. It follows, that under this model, the potential energy reduction is signicantly lower. Finally, based on our model, we show the intimate relation between network coding and queueing networks with negative and positive customers [2].

Details can be found in, for instance:

- Goseling, J., Matsumoto, R., Uyematsu, T., Weber, J.H.: On the energy benefit of network coding for wireless multiple unicast. In: IEEE International Symposium on Information Theory, 2009. ISIT 2009. pp. 2567–2571 (2009)
- Goseling, J., Boucherie, R., van Ommeren, J.K.: Energy consumption in coded queues for wireless information exchange. In: Workshop on Network Coding, Theory, and Applications. NetCod '09. pp. 30–35 (2009)

4   Current and Future Work

So far, we have established lower bounds on the potential energy savings of network coding. In future work we intend to also consider upper bounds to the savings, *i.e.*, ask ourselves how much network coding can help at most.

Preliminary results show, that given stochastic arrivals, large energy savings can only be obtained by allowing for a large delay. In general, however, very little is known about the continuous-time Markov processes arising from wireless networks that employ coding. We will investigate in more detail the fundamental characteristics of these processes.

References

1. Fragouli, C., Soljanin, E.: Network coding fundamentals. Foundations and Trends in Networking 2(1), 1–133 (2007)
2. Gelenbe, E.: Product-form queueing networks with negative and positive customers. Journal of Applied Probability 28(3), 656–663 (1991)