Relaying in Wireless Access Networks –

A Capacity and Energy-Efficiency Perspective

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Abstract

Multi-hop wireless access networks face a number of challenges, yet might be attractive to provide improvements in capacity in energy efficiency. This extended abstract describes the research objectives of the recently started IBMS^2 project that aims at using relay networks, with HiperLAN/2 as a case study, to provide such improvements. In particular, the need for early implementations of HiperLAN/2 to use in testbed setups for experimental investigations is emphasized.

Introduction

The Book of Visions 2000 has drawn attention to the challenges in multi-hop wireless access networks. One obvious benefit of multi-hop access networks is their potential to extend the coverage of radio access networks without requiring any fixed infrastructure. In addition to the coverage aspect, multi-hop architectures also have repercussions on the available capacity in access networks and on the energy efficiency of such systems. As spectrum and hence capacity has recently become a very expensive commodity, and as energy efficiency is an important characteristic of any system where participants are mobile or for other reasons not connected to power supplies with reasonable capacity, these characteristics are important goals for system optimization.

This abstract describes the IBMS^2 (Integrated Bandwidth-efficient Mobile Software-Radio System). IBMS^2 is part of the HyerNET program of the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung) and is a joint research effort by Technical University Dresden, IHP Frankfurt/Oder, Infineon, Systemonic, and Technical University Berlin. This abstract concentrates on system and protocol aspects, which are the main contribution of Technical University Berlin to this project.

Concept Overview

Consider a cellular radio access network with a fixed infrastructure. In cellular networks, spectrum and hence the capacity within a cell is a valuable resource. One of the limiting factors on capacity, given a certain fixed amount of spectrum, is the interference at both the base station and the mobile terminals. One source of interference is the transmission energy of other mobiles or base station. Yet modern cellular systems already employ power control mechanisms to transmit as little power as possible - it is hence not possible to lower the amount of transmitted power directly.

However, it is possible to exploit some properties of electromagnetic wave propagation to overcome this obstacle: The transmission energy necessary to span a distance of x meters (at a fixed error rate) typically grows like the second, third, or fourth power of x (depending on the environment and other factors). Put the other way around, cutting the distance in half reduces the required energy by more than fifty percent. Hence, it appears feasible not to have base station and mobile terminals communicate directly, but to use relay nodes in between. By virtue of the lower transmission energy, it is possible to conjecture that also the interferences will be reduced, possibly enlarging the total capacity in a cell.

One reason why this could increase capacity is the fact that mobile terminals far away from the base station will reduce their transmission power, resulting in lower interference towards the middle of neighboring cells. Thus, close to the neighboring base station, the signal to interference ratio is improved, and either the packet error rate is improved (at a fixed modulation) or a "faster" modulation could be used (at a constant packet error rate), both resulting in improved goodput and hence larger capacity.

Additionally, as the scheme is based on reducing transmission energy, it might also be possible to improve energy efficiency in a cellular network. The benefit in lower total transmission power by using relaying has already been described, however, processing in intermediate nodes does consume energy. Yet this is energy that is going to decrease with additional progress in hardware design and technology. The acceptance of such a system design to end users with limited battery capacity is still an open question.

An important issue is how to realize the relay nodes. While it might make sense in some scenarios to deploy fixed, non-mobile relay nodes (being only depending on a power supply but not needing network connectivity), it is a more promising research question how the mobile terminals themselves could take on the task of relaying traffic of other nodes. This is meant by "single-hop relay" and is suggested and investigated by the $IBMS^2$ project.

Conceptually, single-hop relay should work with many different radio technologies. In the future, an interesting extension of the single-hop relay concept would be to use different radio technologies between base station and relaying node on the one hand and between the relay and the mobile terminal on the other hand. Doing so requires, however, a flexible radio modem. Studying the implementation of such flexible radio modem is another aspect of the $IBMS^2$ project as a whole (our group does not focus on this issue). As a first step, such a flexible radio modem should be designed that implements one current wireless standard; out of several possibilities, HiperLAN/2 has been chosen. Hence, HiperLAN/2 serves also as a basis for the investigations of our group inasmuch as the concrete radio technology in use has any bearings on the concept of single-hop relay in general. One important consequence of the choice of HiperLAN/2 is that the ramifications on TDMA-based MAC protocols on the design of multi-hop relay networks will be considered.

Research Approach

Research activities within $IBMS^2$ at Technical University Berlin will focus mainly on simulation and experimental-based investigations. With regards to simulations, a number of system concepts and scenarios has been identified, and implementation of the relevant aspects of both a general TDMA simulation as well as a more detailed implementation of

HiperLAN/2 are currently under way (using the OMNet++ discrete event simulation tool); first results are expected to be available within a few weeks.
To perform experimental investigations, however, access not only to hardware but also to firmware/software of actual HiperLAN/2 implementations would be very beneficial. In particular, the actual relaying function (how to organize the cell and relay structure in a HiperLAN/2 cell), support for multi-hop routing (how to obtain information about interference power), but also actual measurements of the energy consumption of real HiperLAN/2 devices would be highly beneficial. Perhaps this initiative could serve as basis upon which to build such a testbed.

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