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Efficient Use of Resources in Mobile Ad Hoc Networks

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Efficient use of the resources in mobile ad hoc networks (MANETs) is of great importance to maintain the required quality of service and to prolong the network lifetime. The utilization of the resources such as bandwidth and energy depends on a number of conditions such as network size, node density, and load distribution. These conditions are uncontrollable and often vary throughout the operation of the network. In order to efficiently use the resources, the protocols that determine the behavior of the network should dynamically adapt to these changing conditions.

My thesis is that a protocol architecture for MANETs that dynamically adapts to changing conditions based on cooperation and information sharing leads to more efficient use of the system resources compared to competition based architectures. In particular, in this dissertation we explore the benefits of adaptation based on cooperation and information sharing at the medium access control (MAC) and network (routing) layers of the protocol stack.

At the MAC layer, we develop an analytical model that reflects the relation- ships between protocol parameters and the overall performance of the protocol under various network conditions. This model reveals that the protocol parameters at the MAC layer can be adjusted to make best use of the channel resources depending on the application requirements and network conditions obtained through information sharing, such as average network load density. In order to provide a dynamic system that adapts not only to changing conditions but also to spatially non-uniform traffic load distributions, a lightweight dynamic channel allocation algorithm and a cooperative load balancing algorithm that facilitate efficient use of resources based on local information sharing are proposed. Through extensive simulations, we show that both dynamic channel allocation and cooperative load balancing improve the bandwidth efficiency under non-uniform load distributions compared with protocols that do not use these mechanisms as well as compared with the IEEE 802.11 uncoordinated protocol.

Properly routing the data over a MANET is another challenging topic due to the dynamic behavior of the network, yet it is also crucial in terms of efficient use of resources. Two important routing schemes, network-wide broadcasting and multicasting, are investigated for trade-offs and merged into a single frame-work. The framework allows the selection of the optimal routing scheme based on the network conditions obtained through information sharing, leading to the best use of the system resources in terms of spectrum efficiency and energy efficiency. The interaction of a network with other networks coexisting at the same site also strongly determines its efficiency. We developed an approach for symbiotic networking using hybrid nodes, and our results clearly show that symbiotic networking can provide vital support to co-located networks, which is especially important in resource-constrained networks such as MANETs.

Although theoretical analysis and simulations are efficient tools to comparatively evaluate the efficiency of different protocols, they cannot reflect many of the challenges for real implementation of these protocols, such as clock-drift, synchronization, imperfect physical layers, and interference from devices outside of the system. In order to prove the feasibility of the MAC and Network layer algorithms proposed in this thesis, a working prototype system that incorporates these algorithms is implemented on the Microsoft Research's SORA software defined radio (SDR) platform. The experiments with the prototype system show not only the viability of real time communications but also show the resilience of the system against interference.

To sum up, a variety of methods ranging from MAC layer techniques for optimal spatial reuse and dynamic channel allocation, to network layer techniques for optimal data dissemination schemes and symbiotic interactions with co-located networks are described in this thesis. These concepts enable protocol architectures for MANETs that dynamically adapt to changing conditions based on cooperation and local information sharing. The efficient use of the limited bandwidth and energy resources obtained through such protocol architectures with a realistic set of constraints ensure the viability of future applications.