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A New Routing Framework for Mobile Ad Hoc Wireless Networks

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Providing fast and reliable communication in a multi-hop ad hoc wireless network (MANET) is a challenging task, especially when the set of applications for which the use of MANET is envisioned is very diverse, ranging from small-scale static sensor networks to large-scale highly mobile networks. Although many pioneering MANET studies assume 802.11 framework which was originally developed for one-hop WLAN environment, recent studies show that 802.11 does not work well in a multi-hop environment as it experiences significant throughput reduction [1,2]. Therefore, there have been many new algorithms and techniques proposed to solve the throughput deficiency problem in MANET. For example, the physical layer (PHY) needs to account for the unreliability of the wireless channel, so a possible physical layer solution is to use better modulation and coding schemes [3] or to use smart antenna systems [4]. There are also several techniques [5] proposed for the MAC layer in MANET, e.g., transmit power control, multiple-channel, clustering algorithms for centralized MAC approach, reservation-based MAC for real-time traffic, etc.

Given that there are numerous combinations of technologies used at the PHY and MAC layers, network topologies, bandwidth and energy constraints, intended applications, etc., it is virtually impossible to design a single routing framework which could provide optimality in all the performance metrics over a broad range of networking context. In this PhD thesis, we propose a routing framework for large-scale and highly mobile MANET that can support many different types of multi-hop ad hoc applications and can function in various network conditions.

In the first part of this thesis, we investigate possible routing strategies for P2P applications by taking a bottom-up approach. In particular, we use the experimental study and the developed analytical framework to study the impact of physical wireless channel and interference induced by MAC layer on the performance of two major route selection schemes, i.e., (i) Link-Quality Based routing, which selects a multi-hop route based on the estimated route quality in terms of end-to-end BER; and (ii) the conventional Shortest-Path routing (SP), under various scenarios. Later, we propose a practical design of the cross-layer routing protocol that utilizes the signal strength from the physical layer as well as the path length of the route, whereby the chosen route is the one which
guarantees a stable and good quality communication route towards the destination. These estimates are based on the power level of the received MAC frames and the hop count information in a packet. The modified protocol is backed by simulations and results show that better network performance can be achieved compared to conventional AODV. We simulated numerous test scenarios using UDP and TCP traffic and compared performance metrics for the original and modified versions of the protocol. We were able to achieve (1) A significant reduction in packet latency, (2) An increase in packet delivery ratio in both UDP and TCP traffic.

In the second part of this thesis, we focus on the design of the broadcast protocol where we use a top-down approach to study the impact of different applications and network topologies on the design of the routing protocol. More specifically, we consider a vehicular ad hoc wireless network (VANET) for our case study as we anticipate that ad hoc wireless communication devices will be deployed for practical use in commercial vehicles in the near future. Because the network topology and several applications for VANET are already well defined, routing protocols for VANET should also take into account specific requirements imposed by various VANET applications and different road or traffic conditions. Given that most VANET applications rely heavily on broadcast transmission, we first quantify the impact of broadcast contention in VANET and propose three novel distributed broadcast suppression techniques for a well connected network.

In addition to reducing network contention, a good routing protocol should be scalable, reliable, and efficient in light to moderate traffic conditions as well as in the network with high connectivity. Hence, in the third part of the thesis, we use empirical traffic data collected over the course of 24 hours as our reference to develop an analytical traffic model which can be used to study well-connected and sparsely connected networks. The developed model can also be used to provide a first-cut analysis of the ideal routing performance in a network with low connectivity based on the store-carry-forward routing mechanism. Finally, we combined the techniques previously proposed to cope with the broadcast storm and disconnected network problems and proposed a Distributed Vehicular Broadcast Protocol that is robust against all types of traffic conditions.