Chapter 22

Application-Driven Routing in Wireless Sensor Networks

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ABSTRACT

Sensor networks are built from tiny, resource limited nodes, which are able to communicate with each other, and thus, provide distributed services. The quality of communication, and especially of routing, is one of the major enablers of good performance, energy efficiency, and longevity in resource-deprived sensor networks. Since the advent of wireless sensor networks, literally hundreds of routing algorithms, tailored especially for this domain, have been proposed in the literature. This chapter highlights the main ideas and illustrates how these solutions help to reach various design goals. After a general overview, the taxonomy of routing algorithms in sensor networks will be presented, and then the mainstream algorithms, with the greatest impact on the field, will be introduced and analyzed. Through typical routing algorithms, we will show how and what kind of quality of services can be provided for various application needs.

INTRODUCTION

Sensor networks, constituting a special realm of wireless ad-hoc networks, offer a diverse set of exciting new ubiquitous application domains. The network is composed of tiny autonomous sensor nodes, which are possibly embedded or otherwise distributed in our environment in large quantities, and can perform distributed sensing, with spatial resolution and coverage that was impossible with ordinary measurement systems before. The nodes in the network communicate with each other and form a distributed, collaborative sensing and computing domain.

The application of sensor networks is motivated by both civil and military needs, including environment and habitat monitoring, intelligent agriculture, industrial monitoring, healthcare...
applications, traffic surveillance in the civilian domain; and various military applications, e.g., battlefield surveillance, intruder detection and tracking, and shooter localization, just to name a few. Sensor nodes typically contain a low-power microcontroller, radio transceiver, and energy resources (typically batteries, but energy harvesting is also possible, e.g., from solar energy or motion). Sensing capabilities include temperature, humidity, pollution, motion, sound, but any application-specific sensor can also be applied. The hardware and software architecture of the nodes is designed to support long, autonomous operation. A comprehensive overview on sensor networks can be found in (Yick, Mukherjee, Ghosal, 2008).

The communication between nodes is typically performed by radio in one of the free ISM bands, using multi-hop, ad-hoc networking. Sensor networks typically contain special devices (base stations) to provide gateways to external devices or networks. The majority of applications send collected data to the base stations, requiring unicast (also called convergecast) services. User commands or system maintenance messages are typically sent from base stations to all nodes or a set of nodes, using multicast routing services. Peer-to-peer routing is relatively rare, but occasionally present in sensor networking applications.

No matter what types of services are used in the network, routing is one of the major middleware services that define the performance of the overall network. Due to the special architecture and requirements present in sensor networks, traditional solutions, developed for wired or general wireless networking domains, are not applicable here. Thus literally hundreds of routing algorithms, specially tailored for sensor networks, can be found in the literature, and the number is still counting. An excellent review on various protocols can be found in (Akkaya and Younis, 2005). This chapter highlights the main and basic ideas present in various routing algorithms, and illustrates how these solutions help to reach various design goals.

First, the special challenges, resulting from the hardware/software constraints and the application domain, are discussed, and then the taxonomy of the typical routing algorithms in sensor networks is briefly presented. Finally, the mainstream algorithms with the greatest impact on the field will be introduced and analyzed. Through typical routing algorithms, we will show how different quality of services can be provided for various application needs.

**CHALLENGES IN SENSOR NETWORKS**

Routing algorithms are affected by the special needs, constraints, and requirements of sensor networking applications. Some of the requirements are derived from physical constraints; others are driven by the special needs of the applications.

- **Resource-limited nodes.** Large sensor networks necessitate the usage of inexpensive devices. This results in limited processing power (8-bit microcontrollers are common), small storage resources (both for program and data), and limited communication capabilities. Apart from expenses, the other limiting factor is energy. Most devices are driven from batteries, from which the system should operate for months or years, without user intervention. Thus low energy consumption is necessary. Since nodes in wireless sensor networks serve as both sensors and routing devices, the routing protocol has great impact on the nodes’ energy consumption. Another serious limitation is the wireless communication channel’s limited bandwidth and its traditional problems (fading, large error rate).

- **Ad-hoc deployment, unmanaged networks.** In many applications deployment of the nodes is not manageable, thus self-organizing network solutions are required.
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