Chapter X
Wireless Ad Hoc Networks: Design Principles and Low Power Operation

Veselin Rakocevic
City University, UK

Ehsan Hamadani
City University, UK

ABSTRACT

Seamless communication between computing devices is an essential part of the new world of ubiquitous computing. To achieve the concept of a "disappearing computer," it is necessary to establish reliable and simple communication principles to enhance the usability and the efficiency of the ubiquitous computing devices. It is also important to use wireless links and to enable devices to quickly create and manage networks ad hoc, without any need for network infrastructure. This chapter presents the design principles for such networks. The main features of these networks are analysed, including the principles of medium access control and routing, along with the current standardisation and development activities. Special attention is paid to the low power design of wireless ad hoc networks. Low power design is important because of the predicted self-organisation, small size, and extended scalability of ubiquitous computing networks. In such an environment, it is important to extend the network lifetime by deploying power sensitive network algorithms and protocols.

INTRODUCTION

Ubiquitous computing paradigm assumes the existence of networks of computing devices capable of processing and exchanging data. Since the essence of ubiquitous computing is the invisibility of the computing system, it is paramount that these networks use wireless links, that they are easy to implement and easy to scale, and that they provide reliable and robust communication

capabilities. Recent advances in both hardware and software have initiated a small revolution in wireless devices able to communicate without any help from network infrastructure, that is, in a so-called ad hoc mode. They are characterized by high flexibility and scalability, ease of deployment, and simplified network management.

Ad hoc networks have initially been used in military applications. The need for rapid deployment of a communication network in environments that have no infrastructure support was the main motivation behind the projects such as PRNet and SURAN (Freebersyser & Leiner, 2001) and LPR (Fifer & Bruno, 1987). During the last decade, with the emergence of cheap hardware solutions, the research in mobile ad hoc networking has in addition concentrated on non-military applications. Typical applications for wireless ad hoc networks include their use in sensor networks, especially in medical applications, for emergency services, in commercial use for "smart home" networking, for location-aware applications, for environment monitoring, agriculture, production, and so forth.

Ad hoc networks are especially interesting because their independent nature enables us to think about tailored design of network protocols and interfaces. For example, if the key requirement for a sensor network is for a network to be active for as long as possible, the network protocols must be designed to minimise the power consumption regardless of other, more traditional requirements for maximising the throughput, or minimising the delay. On the other hand, if the key requirement is the reliability of communication, the network has to be designed in a way that ensures that the data must arrive at the destination point regardless of the increased delay or the decreased throughput (this can be done for example by increasing the number of link-layer retransmissions). This approach is fundamentally different from the typical approach to networking inherited from TCP/IP networks, where the long process of standardization forced researchers to think globally and work toward unique solutions with ubiquitous application.

Recent experience in ubiquitous systems prototyping has taught us that the key issue in successful connection of computing devices does not lie in their battery life, processing power, or low-level network connectivity, but in the fact that devices could not work together unless they have been specifically programmed to talk to each other (Edwards, Newman, Sedivy, & Smith, 2005). This important fact is crucial for understanding the complexity of network design for ubiquitous computing. However, throughout this chapter, we will focus on the principles of networked communication specific for the wireless ad hoc environment. We assume that interoperability, middleware design, and interfacing will be covered in more detail in other chapters and will focus on general networking principles such as routing, medium access control, and, especially, power management.

To start with, we can say that the main characteristics of ad hoc networks include:

- The lack of network infrastructure
- Mobility of connected nodes
- Multihop routing of data packets
- Need for low power consumption

Ad hoc networks do not depend on any established network infrastructure. This has great impact on network design—there is no centralised intelligence responsible for network management, traffic engineering, and network security. Node discovery and connectivity mechanisms have to be distributed which puts greater strain on limited processing power in connected nodes. Mobility of the nodes stems either from the independent movement of the nodes or from the external activities and/or phenomena that influence the mobility (e.g., sensor nodes thrown from an airplane are highly mobile because they are thrown around by winds). The mobility of nodes creates numerous problems for successful network protocol design.