Chapter 79
A Survey of MAC Layer Protocols to Avoid Deafness in Wireless Networks Using Directional Antenna

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ABSTRACT

Directional antennas have gained immense popularity among researchers working in the area of wireless networks. These antennas help in enhancing the performance of wireless networks through increased spatial reuse, extended communication range, energy efficiency, reduced latency, and communication reliability. Traditional Medium Access Control (MAC) protocols such as IEEE 802.11 are designed based on use of omnidirectional antennas. Therefore, suitable design changes are required to exploit the benefits of directional antennas in wireless networks. Though directional antennas provide many benefits to enhance network performance, their inclusion in the network also results in certain challenges in network operation. Deafness is one such problem that occurs among nodes using directional antennas. This chapter concentrates on the problem of deafness, which is introduced due to the use of directional antennas in wireless ad-hoc, sensor, and mesh networks. Many researchers have provided numerous solutions to deal with the problem of deafness in these networks. In this chapter, the authors first explain the problem of deafness and then present an extensive survey of solutions available in the literature to deal with the problem of deafness in wireless ad-hoc, sensor, and mesh networks. The survey is accompanied by a critical analysis and comparison of available solutions. Drawbacks of available solutions are discussed and future research directions are presented.

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INTRODUCTION

Numerous technological advances and easy access to wireless devices have seen increased research interest in wireless networks. Traditional wireless networks are mainly infrastructure based where nodes communicate through base station or access point. In such networks, nodes are required to be within the range of infrastructure. Such networks are called as single-hop networks. With introduction of cheaper hardware, faster processors and smaller transceivers; focus turned towards ad-hoc networks. In ad-hoc networks, nodes communicate without an access point or base station. In such networks, a node is capable of acting as a source, sink or router of information. This concept gave rise to multi-hop communication. Further research and technological advances introduced the concept of wireless mesh networks (WMNs) and wireless sensor networks (WSNs), mobile ad-hoc networks (MANETs) and vehicular ad-hoc networks (VANETs) to name a few. IEEE provided standardized protocols and techniques for physical and MAC layer operations in these networks. These protocols assumed use of omnidirectional antennas in the network. With growing research interest in wireless networks, researchers started to study challenges faced by wireless networks and ways to overcome these challenges. Some of the challenges that researchers tried address were interference, spatial reuse, energy efficiency, latency in communication and information security. This is when researchers proposed to exploit the benefits of directional antenna / antenna beamforming. Many researchers proposed the use of directional antennas in wireless networks and proved their benefits through simulations and analysis. However, it was noted that traditional MAC protocols failed to work with directional antennas, and despite numerous benefits that directional antennas provided, they could not be used directly in wireless networks. Use of directional antennas introduced new problems in network operation. Deafness, new hidden terminal, asymmetry in gain, and need for location information of destination node for antenna beamforming were some of such problems that researchers needed to work upon. The aim of this chapter is to provide an extensive survey of solutions to mitigate deafness available in the literature. Though there are surveys available for protocols based on directional MAC, not many surveys are available which concentrate only on the problem of deafness occurred due to the use of directional antennas. Some of the researchers have presented surveys of deafness solutions, i.e., Choudhury and Vaidya (2004) and Gossain, Cordeiro, Cavalcanti, and Agrawal (2004). These surveys are outdated and focus only on ad-hoc networks. In this chapter, the authors concentrate on the problem of deafness introduced due to the use of directional antennas in the network. This chapter is targeted towards wireless networks researchers who want to pursue their research in area of wireless networks using directional antennas. The main objective of this chapter is to make the readers aware of the problem of deafness and present them with ongoing research and future research directions to combat this problem. For this, the authors provide an extensive literature survey of solutions available in literature to deal with the problem of deafness in wireless ad-hoc, sensor and mesh networks. This is accompanied with critical analysis and comparison of surveyed solutions highlighting their benefits and drawbacks. Based on this the authors provide scope and directions for future research.

We first provide the readers with brief introduction to directional antennas. The authors first discuss the use of Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) protocol for medium access control in wireless networks followed by introduction to the problem of deafness. It is important to analyze the benefits and drawbacks of using directional antennas in wireless networks in order to understand and appreciate the methods used to deal with deafness. Therefore, the authors first discuss the advantages and disadvantages of