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Medium Access Control protocols for ad hoc wireless networks: A survey

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Abstract

Studies of ad hoc wireless networks are a relatively new field gaining more popularity for various new applications. In these networks, the Medium Access Control (MAC) protocols are responsible for coordinating the access from active nodes. These protocols are of significant importance since the wireless communication channel is inherently prone to errors and unique problems such as the hidden-terminal problem, the exposed-terminal problem, and signal fading effects. Although a lot of research has been conducted on MAC protocols, the various issues involved have mostly been presented in isolation of each other. We therefore make an attempt to present a comprehensive survey of major schemes, integrating various related issues and challenges with a view to providing a big-picture outlook to this vast area. We present a classification of MAC protocols and their brief description, based on their operating principles and underlying features. In conclusion, we present a brief summary of key ideas and a general direction for future work.
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1. Introduction

Back in the 1970s, the Defense Advanced Research Projects Agency (DARPA) was involved in the development of packet radio networks for use in the battlefields. Around the same time, the ALOHA [1] project used wireless data broadcasting to create single hop radio networks. This subsequently led to development of the *multi-hop* multiple-access Packet Radio Network (PRNET), which allowed communication coverage over a wide area. The term *multi-hop* refers to the fact that data from the source needs to travel through several other intermediate nodes before it reaches the destination. One of the most attractive features of PRNET was rapid deployment. Also, after

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installation, the whole system was self-initializing and self-organizing. The network consisted of mobile radio repeaters, wireless terminals and dedicated mobile stations. Packets were relayed from one repeater to the other until data reached its destination.

With the development of technology, devices have shrunk in size and they now incorporate more advanced functions. This allows a node to act as a wireless terminal as well as a repeater and still be compact enough to be mobile. A self-organizing and adaptive collection of such devices connected with wireless links is now referred to as an *Ad Hoc Network*. An ad hoc network does not need any centralized control. The network should detect any new nodes automatically and induct them seamlessly. Conversely, if any node moves out of the network, the remaining nodes should automatically reconfigure themselves to adjust to the new scenario. If nodes are mobile, the network is termed as a *MANET* (Mobile Ad hoc NETwork). The Internet Engineering Task Force (IETF) has set up a working group named MANET for encouraging research in this area [2].

Typically, there are two types of architectures in ad hoc networks: flat and hierarchical [3,6]. Each node in an ad hoc network is equipped with a transceiver, an antenna and a power source. The characteristics of these nodes can vary widely in terms of size, processing ability, transmission range and battery power. Some nodes lend themselves for use as servers, others as clients and yet others may be flexible enough to act as both, depending on the situation. In certain cases, each node may need to act as a router in order to convey information from one node to another [4,5].

1.1. Applications

Coupled with global roaming capabilities and seamless integration with existing infrastructure, if any, ad hoc wireless networks can be used in many new applications [6,8]. In case of natural or other disasters, it is possible that existing communication infrastructure is rendered unusable. In such situations, an ad hoc wireless network featuring wideband capabilities can be set up almost immediately to provide emergency communication in the affected region. In mobile computing environments, mobile wireless devices that have the capability to detect the presence of existing networks can be used to synchronize data with the user's conventional desktop computers automatically, and download appointment/schedule data. A user carrying a handheld Personal Digital Assistant (PDA) device can download *Context sensitive data* in a shopping mall or museum featuring such wireless networks and services. The PDA would be able to detect the presence of the network and connect itself in an ad hoc fashion. Depending on the user's movement, the PDA can poll the network for relevant information based on its current location. For instance, if the user is moving through the clothing section of the shopping mall, information on special deals or pricing can be made available. Similarly, ad hoc networks can be used in travel-related and customized household applications, telemedicine, virtual navigation, etc.

1.2. Important issues

There are several important issues in ad hoc wireless networks [3,6–8,70]. Most ad hoc wireless network applications use the Industrial, Scientific and Medical (ISM) band that is free from licensing formalities. Since wireless is a tightly controlled medium, it has *limited channel bandwidth* that is typically much less than that of wired networks. Besides, the wireless medium is inherently *error prone*. Even though a radio may have sufficient channel bandwidth, factors such as multiple access, signal fading, and noise and interference can cause the *effective throughput* in wireless networks to be significantly lower. Since wireless nodes may be mobile, the *network topology* can change frequently without any predictable pattern. Usually the links between nodes would be *bi-directional*, but there may be cases when differences in transmission power give rise to *unidirectional links*, which necessitate special treatment by the Medium Access Control (MAC) protocols. Ad hoc network nodes must *conserve energy* as they mostly rely on batteries as their power source. The *security* issues should be considered in the overall network design, as it is relatively easy to eavesdrop on wireless transmission. *Routing protocols* require information

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