Wireless Ad Hoc Networking

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INTRODUCTION

Mobile ad hoc networks represent a new form of communication consisting of mobile wireless terminals (e.g., handset, PDAs, notebooks). These type of networks are wireless multi-hop packet networks without any fixed infrastructure and centralized administration, in contrast to today's wireless communications, which is based on a fixed, pre-established infrastructure. The design of wireless ad hoc networks faces many unique challenges. In this article, mobile ad hoc networks and their characteristics are described, and the design issues, applications and future trends of such networks will be discussed.

BACKGROUND

In recent years, widespread availability of wireless communication and handheld devices stimulated the research and development on self-organizing networks that do not require a pre-established infrastructure and any centralized architecture. Those spontaneous networks provide mobile users with ubiquitous communication capability and information access regardless of their location. This type of networking is called mobile ad hoc networks.

The idea of mobile ad hoc networks has been under development from the 1970s and 1980s in the framework of Mobile Packet Radio Technology (PRNET-1973) (Jubin & Tornow, 1987) and Survivable Adaptive Networks (SURAN-1983) (Schacham & Westcott, 1987). These projects supported research on the development of automatic call set up and maintenance in packet radio networks with moderate mobility. However, interest in this area grew rapidly due to the popularity of a large number of portable digital devices, such as laptop and palmtop computers, and the common availability of wireless communication devices.

In the middle of the 1990s, with the definition of standards, commercial radio technologies have begun to appear and the wireless research community identified in ad hoc networks a challenging evolution of wireless networks. The success of a network technology is associated with the development of networking products that can provide wireless network access at a competitive price. A major factor in achieving this goal is the availability of appropriate networking standards. Today's emerging standards and technologies for constructing a mobile ad hoc network are IEEE 802.11, Bluetooth and ETSI Hiperlan/2. The deployment of mobile ad hoc networks opens a wide-range of potential utilisation from military to miscellaneous commercial, private and industrial scenarios (Perkins, 2001).

MOBILE AD HOC NETWORKS AND THEIR CHARACTERISTICS

A mobile ad hoc network (MANET) consists of a collection of mobile wireless and autonomous hosts –in this sense simply referred to as "*nodes*"– which spontaneously form a temporary network. The devices may be of various types (e.g., notebook computers, PDAs, cell phones, etc.) and various capacities (e.g., computing power, memory, disk, etc.).

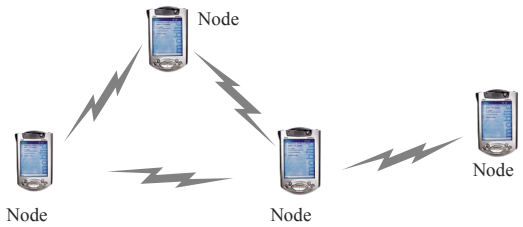
The most important characteristic of such a network is its independence of any fixed infrastructure (e.g., base station or access point) or centralized administration. All networking functions, such as determining the network topology, multiple access, and routing of data over the most appropriate paths, must be performed in a distributed way. These tasks are particularly challenging due to the limited communication bandwidth available in the wireless channel.

Actually, the idea of ad hoc networking is sometimes also called infrastructureless networking (Frodigh, Johansson & Larsson, 2000). An ad hoc network is able to operate autonomously and is completely self-organized and self-configured. Therefore, it can be easily and rapidly installed. In an ad hoc environment people and vehicles can be interworked in areas without a pre-existing communication infrastructure, or when the use of such infrastructure requires wireless extension.

Autonomous nodes may move arbitrarily so that the topology changes frequently without any prior notice. The wireless transmission range of the nodes is also limited; therefore the connection (e.g., wireless link) between the neighboring nodes may break as soon as they move out of range. Consequently, topology of the network and the interconnection patterns among nodes may change dynamically so that links between nodes become unusable. Because of the dynamic nature of ad hoc networks, new routes must be considered and maintained using routing protocols.

Another important property of ad hoc networks is the multi-hop capability. It is given that cellular networks — also called single-hop networks — rely on a fixed wired infrastructure to achieve the task of routing and maintain the

Figure 1. A mobile ad hoc network



connection end-to-end. On the contrary, a mobile node in an ad hoc network that cannot reach the destination directly, because it does not lie within its radio transmission range, will need to relay its information flow through other nodes. This implies the mobile hosts to incorporate routing functionality so that they can act both as routers and hosts.

Other important characteristics of MANET include (Perkins, 2001):

- **Dynamic topologies:** Nodes are free to move arbitrarily; thus, the network topology may change randomly and rapidly at unpredictable times.
- **Bandwith-constrained links:** Caused by the limits of the air interface. Furthermore, multiple access, multipath fading, noise and signal interference decrease the limited capacity available at the allocated frequency rate.
- **Energy-constrained operation:** MANETs inherently imply an underlying reliance on portable, finite power sources.
- **Limited security:** Mobile networks are in general more vulnerable to eavesdropping, spoofing and denial-of-service attacks than fixed-cable networks.

DESIGNING ISSUES

Physical Layer and MAC Layer

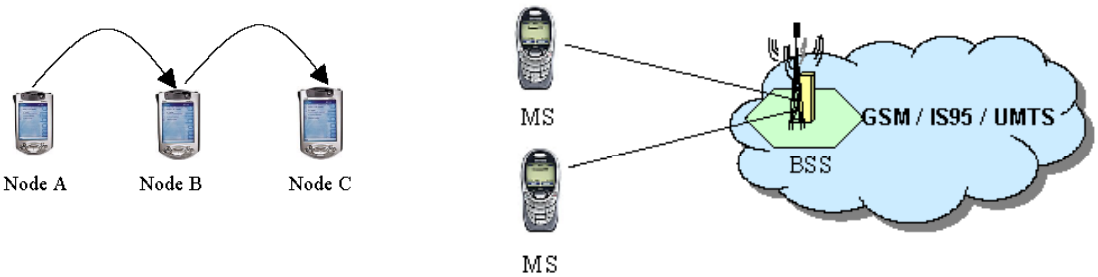
A well-designed architecture for mobile ad hoc networks involves all networking layers, ranging from the physical layer to the application layer. Information as node distribution, network density, link failures, and etcetera, must be shared among layers, and the MAC (medium access control) layer and the network layer need to collaborate in order to have a better view of the network topology and to optimise the number of messages in the network (Bruno, Conti, & Gregori, 2001; Kurose, Schwartz, & Yemini, 2000).

The main aspects of designing the physical transmission system are dependent on several characteristics of the radio propagation channel such as path loss, interference and fading. In addition, since mobile terminals usually have limited power resources, the transceiver must be power efficient. These aspects are taken into account while designing the modulation, coding, and power control features in the radio equipment. In principle, the radio equipment in the nodes forming a mobile ad hoc network can use any technology as long as it provides reliable links between neighboring mobile terminals on a common channel. Candidate physical layers that have gained prominence are infrared and spread spectrum radio techniques.

The MAC (medium access control) layer plays the key role in determining the channel usage efficiency by resolving contention amongst a number of unsupervised terminals sharing the common channel. An efficient MAC protocol allows coordinated access to the limited resources. The main goal of a MAC protocol is therefore maximizing the probability of successful transmissions and maintaining fairness amongst all users.

Though research on medium access schemes for wired local area networks (LANs) have been done for many years, the same concepts cannot be directly applied to wireless

Figure 2. Mobile ad hoc networks (multi-hop networks) in comparison to today's cellular (single-hop) networks



(Node C is reached from node A via node B in multihop way)