Mobile Ad Hoc Networks

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INTRODUCTION

This chapter offers a state-of-the-art review in mobile ad hoc networks (MANETs). It first introduces the history of ad hoc networks, explaining the ad hoc network concept and referring to the main characteristics of these networks and their fields of application.

It then focuses on technologies and protocols specific to ad hoc networks. Firstly, it refers to relevant proposals targeting the PHY/MAC layers. Secondly, it discusses the different routing protocol proposals for ad hoc networks according to the category to which they belong. Finally, it includes an overview of the different protocols proposed for ad hoc networks at the transport layer. The chapter concludes with some remarks on future trends in these networks.

BACKGROUND

The history of wireless networks dates from the 1970s. In fact, radio communications and computer networks were first combined by the University of Hawaii, in 1971, in an experimental network named ALOHANET. That network offered bidirectional communications following a star topology, and its purpose was to allow communicating with US mainland. During the 1980s, the technology was improved, and towards the end of the 1990s, interest on wireless networks reached a peak, mainly due to the fast growth of the Internet.

Nowadays we can split existing wireless networks into different categories according to their scope and size. Wireless wide area networks (WWANs), such as GSM and UMTS (Ojanpera, T. & Prasad, R., 1998), usually cover hundreds of kilometers and use private frequency bands. Such networks are usually owned and maintained by telecommunications providers, and their purpose is to offer services in a country or a region of it. Wireless metropolitan area networks (WMANs), such as WiMax (IEEE 802.16 WG, 2004), typically have a range of a few kilometers, and can operate over both private and public frequency bands, so that both telecommunication companies and private users can take advantage of them. Wireless local area networks (WLANs), such as WiFi (IEEE 802.11 WG, 1999), usually cover areas between a few tens of meters up to a kilometer. They typically use public frequency bands so that users can freely install and use them. At the lower end, we have wireless personal area networks (WPANs), such as Bluetooth (IEEE 802.15 WG, 2005), which also use free frequency bands that are used to replace cables within a very limited area around a single user (few meters).

This chapter focuses on recent developments in terms of infrastructure-less wireless networks, more commonly known as ad hoc networks, that extend WLAN technologies to offer more flexible solutions. All nodes within an ad hoc network provide a peer-level multihopping routing service to allow out-of-range nodes to be connected. Unlike a wired network, nodes in an ad hoc network can move freely, thus giving rise to frequent topology changes.

Such a network may operate in a stand-alone fashion or be connected to the larger Internet. An ad hoc architecture has many benefits, such as self-reconfiguration and adaptability to highly variable characteristics, namely, power and transmission conditions, traffic distribution variations, and load balancing. However, those benefits come with many challenges. New algorithms, protocols, and middleware have to be designed and developed to create a truly flexible and decentralized network.

In terms of applications, ad hoc networks offer the required flexibility to adapt to situations where no sort of infrastructure is available. Examples of such situations are army units moving inside hostile territories, or organized teams, such as firemen, performing rescue tasks. In general, mobile ad hoc networks can be used on all those situations characterized by lack of fixed infrastructure, peer-to-peer communication, and mobility support.

TECHNOLOGIES AND PROTOCOLS FOR AD HOC NETWORKS

A. PHY/MAC Layer Technologies

Throughout the past few years, novel solutions for MAC/PHY layers have been sought in the wireless ad hoc networking field. In particular, there have been several proposals targeting the MAC layer (Kumar, Raghavan, & Deng, 2006).

Despite the many proposals available, very few have made it to the market. Nowadays, almost every ad hoc network relies on IEEE 802.11 technology (IEEE 802.11 WG, 1999), which defines both physical and MAC layers. Since this standard has gained much relevance, we now offer more details about it.

In 1997, IEEE group 802.11 was created. The purpose was to create a technology for wireless local area networks operating on ISM (industrial, scientific, and medical) frequency bands. With that purpose, a MAC layer and three different physical layers were defined, operating at 1 and 2 Mbit/s:

- Infrared (IR) – baseband
- Frequency hopping spread spectrum (FHSS) – 2.4 GHz band
- Direct sequence spread spectrum (DSSS) – 2.4 GHz band

In December 1999, the IEEE 802.11a standard was completed, proposing a different technique for the physical layer named orthogonal frequency division multiplexing (OFDM). This technology was able to offer up to 54 Mbit/s on the 5 GHz band. A year later, in January 2000, the IEEE 802.11b standard was completed, consisting basically of an extension to the original standard, offering up to 11 Mbit/s on the 2.4 GHz band. Only in July 2003 was the IEEE 802.11g standard completed, offering 54 Mbit/s speeds on the 2.4 GHz frequency band. Recently, the 802.11n group is proposing higher speed extensions to the standard, targeting data rates above 300 Mbit/s.

Concerning 802.11's MAC layer, its main functions are reliable data delivery, fair access to the wireless media, and data protection. Moreover, it is responsible for a correct operation in noisy, unreliable environments.

The 802.11 standard offers two different medium access mechanisms:

- Distributed coordination function (DCF), a mandatory access mechanism based on CSMA/CA. (*carrier sense multiple access with collision avoidance*).
- Point coordination function (PCF), optional, based on a polling method to support services with time restrictions.

Since the latter only applies to access points, in ad hoc networks, the DCF must be used instead. Despite that the ad hoc mode proposed by the IEEE 802.11 standard did not specifically target multihop ad hoc networks, it is widely used and offers relatively good performance.

B. Routing Protocols

A routing protocol is required when a packet must go through several hops to reach its destination. It is responsible for finding a route for the packet and making sure it is forwarded through the appropriate path.

Routing techniques used can be divided into three families: *distance vector* (Bellman, 1957; Ford & Fulkerson, 1962), *link state* (Dijkstra, 1959), and *source routing* (Estrin, Li, Rekhter, Varadhan, & Zappala, 1996).

Internet routing protocols, based on these techniques, generate periodic control messages, a procedure that is not adequate for a large mobile network with long routes since it would result in a large number of control messages. Reducing routing overhead is critical for mobile nodes since CPU use, as well as radio transmissions and receptions, would cause batteries to be quickly depleted.

We will now present different routing protocol proposals for MANETs that are currently available. We have organized them into three groups: proactive, reactive, and other strategies, being that the latter embraces all those that do not fall under the former two categories.

Proactive Routing Protocols

When using proactive routing protocols, all the nodes (routers) periodically exchange routing information, with the aim of maintaining a consistent, updated, and complete network view. Each node uses the exchanged information to calculate the costs towards all possible destinations. That way, if a destination is found, there will always be a route available towards it.

The main advantage of proactive routing schemes is that there is no initial delay when a route is required. On the other hand, these are usually related to a greater overhead and a larger convergence time than for reactive routing techniques, especially when mobility is high. To increase the performance in ad hoc networks, both *link-state* and *distance vector* algorithms were modified. Examples of routing protocols using *distance vector* techniques are the *destination-sequenced distance vector* (DSDV) (Perkins & Bhagwat, 1994) and the *wireless routing protocol* (WRP) (Murthy & Garcia-Luna-Aceves, 1996). Examples of *link-state* based protocols are the *optimized link state routing* (OLSR) (Clausen, Jacquet, Laouiti, Muhlethaler, Qayyum, & Viennot 2001), and the *topology broadcast reverse path forwarding* (TBRPF) (Bellur & Ogier, 1999).