Supporting Real-Time Services in Mobile Ad-Hoc Networks

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INTRODUCTION

Mobile ad-hoc networks (MANETs) are well known by their flexibility and usefulness, being an ideal technology to support ubiquitous computing environments. Such environments are expected to support a plethora of applications, including real-time video and voice communications.

In terms of applications, this technology can be used whenever there is a lack of infrastructure for support, which typically occurs in rescue missions, areas affected by natural disasters, remote areas, war scenarios, and also in the underground. The use of real-time voice and video communications could allow, for example, firemen rescue teams to communicate seamlessly and for the head officer to remotely supervise their activity using different video channels.

The deployment of real-time services over mobile ad-hoc networks requires QoS (quality of service) support at different network layers. QoS support is understood as the network ability to offer some guarantees about the traffic being delivered. Within the scope of QoS we often define performance in terms of availability (uptime), bandwidth (throughput), latency (delay), delay jitter, and error rate.

Offering QoS support in mobile ad-hoc network environments is, nevertheless, quite difficult due to the innate complexity of these networks. The problems that impact mobile ad-hoc networks can be split according to the network layer affected.

At the physical layer, frequent topology changes—in conjunction with channel contention and unstable radio links—make real-time services support in such networks very hard to achieve (Georgiadis, Jacquet, & Mans, 2004).

At the Medium Access Control (MAC) layer, channel access is typically distributed, provoking the well-known hidden and exposed node problems, which complicate bandwidth reservation.

At the network layer, routing protocols have to deal with frequent topology changes and simultaneously discriminate among the available paths to meet QoS requirements.

At the application layer, awareness of the type of networks and technologies being used allows applications to adapt themselves according to path conditions and so improve performance.

This article discusses the aforementioned issues related to QoS challenges and solutions in mobile ad-hoc networks. It first includes some background information on the history of QoS support in computer networks. It then refers to the problematic of QoS support in mobile ad-hoc networks by referring MAC and routing layer solutions, along with QoS architectures for ad-hoc networks. To conclude the article there is reference to future trends in terms of QoS support in ad-hoc networks.

BACKGROUND

The first attempts at providing significant QoS support improvements in computer networks took place on the Internet in the early 1990s. The main problem faced by engineers was that the Internet was initially created to handle best-effort traffic alone. This means that its infrastructure was not designed considering QoS-related functionality such as resource reservation, and so all users compete for bandwidth. For this reason the Internet protocol (IP) is connectionless, requiring no set-up “signaling” for admission control.

When enhancements in terms of available bandwidth and a terminal’s capabilities brought up the need for supporting new services on the Internet, preliminary evaluation studies showed that the performance of these new services was very poor due to the best-effort policy. There was, therefore, a need to enhance the Internet infrastructure in order to allow performing resource reservations in a similar fashion to telephony networks. The RSVP protocol (Braden, Zhang, Berson, Herzog, & Jamin, 1997) was created to fulfill this need as part of the Internet's integrated services (IntServ) architecture (Braden, Clark, & Shenker, 1994). RSVP follows a receiver-based model since it is the responsibility of each receiver to choose its own level of reserved resources, initiating the reservation and keeping it active. The actual QoS control, though, occurs at the sender's end. The sender will try to establish and maintain resource reservations over a distribution tree. If a particular reservation is unsuccessful, the correspondent source is notified.

The IntServ architecture proved to be complex and required too many resources, suffering from scalability problems. So, the differentiated services (DiffServ) architecture (Blake, 1998) emerged as a more efficient alternative. In the latter, service-level agreements (SLA) are achieved between different domains. One of the main virtues of the DiffServ architecture is that it drops the traditional concept of signaling, no longer requiring the reservation of resources in all the network elements involved. The strategy consists of performing admission control on domain boundaries, and then treating them in a differentiated manner inside the domain according to packet tagging on the domain borders, which is a much faster and lightweight process.

QoS SUPPORT IN MOBILE AD-HOC NETWORKS

MANET environments differ greatly from the wired environments the DiffServ and IntServ models were created for. The difference stems not only from the new problems encountered in MANETs (mobility, collisions, variable channel conditions, etc.), but also because MANETs do not follow the client/service provider paradigm inherent to both IntServ and DiffServ models. In MANETs the network is typically formed by users that cooperate and, except in situations where there is some centralized management entity (e.g., Army), it depends on the good behavior of users and limited resource sharing. So, new proposals were presented in order to achieve reliable QoS support in MANETs.

In this section we present an overview of the different proposals available in the literature offering QoS improvements to mobile ad-hoc networks. We first introduce QoS proposals at the MAC layer. Then we refer to QoS solutions at the routing layer. Finally we refer to complete QoS architectures for MANETs.

QoS Support at the MAC Layer

Most of the MAC layer protocols for ad hoc networks are characterized by being distributed (there is no central entity regulating channel access) and contention-based (channel access is not deterministic, being that stations compete to gain access to it). These characteristics, along with the well-known hidden (Kleinrock & Tobagi, 1975) and exposed (Shukla, Chandran-Wadia, & Iyer, 2003) node problems that are prone to occur in wireless multi-hop environments, complicate the process of offering QoS support. In fact, in such wireless environments, it is impossible to offer strict QoS guarantees to users, and so statistical QoS is achieved instead.

Despite this is a novel research area, we can already find products in the market offering QoS support at the MAC layer. The most relevant technology available due to its widespread adoption is IEEE 802.11e, which is a new MAC standard proposed by the IEEE 802.11 Working Group (2005) to enhance WiFi networks with QoS support.

The IEEE 802.11e standard relies on a hybrid coordination function, HCF, which defines two medium access mechanisms: the HCF controlled channel access (HCCA) and the enhanced distributed channel access (EDCA). From these two, only EDCA applies to ad-hoc network environments, the former being reserved for access point operation.

QoS support through EDCA requires introducing different access categories (ACs) and their associated backoff entities. Contrarily to the legacy IEEE 802.11 stations, where all the packets received by the MAC layer have the same priority and are assigned to a single backoff entity, IEEE 802.11e stations have four backoff entities—one for each AC—so that packets are sorted according to their priority. Each backoff entity has an independent packet queue assigned to it, as well as a different parameter set.

Table 1. IEEE 802.11e MAC parameters for an IEEE 802.11a/g radio

Access Category	AIFSN	CWmin	CWmax	TXOPLimit (ms)
Background	7	15	1023	0
Best effort	3	15	1023	0
Video	2	7	15	3.008
Voice	2	3	7	1.504

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