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A QoS-aware routing protocol with adaptive feedback scheme for video streaming for mobile networks

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ABSTRACT

One of the major challenges for the transmission of time-sensitive data like video over mobile ad-hoc networks (MANETs) is the deployment of an end-to-end QoS support mechanism. Therefore, several approaches and enhancements have been proposed concerning the routing protocols. In this paper we propose a new QoS routing protocol based on AODV (named AQA-AODV), which creates routes according to application QoS requirements. We have introduced link and path available bandwidth estimation mechanisms and an adaptive scheme that can provide feedback to the source node about the current network state, to allow the application to appropriately adjust the transmission rate. In the same way, we propose a route recovery approach into the AQA-AODV protocol, which provides a mechanism to detect the link failures in a route and re-establish the connections taking into account the conditions of QoS that have been established during the previous route discovery phase. The simulation results reveal performance improvements in terms of packet delay, number of link failures and connection setup latency while we make more efficient use of the available bandwidth than other protocols like AODV and QAODV. In terms of video transmission, the obtained results prove that the combined use of AQA-AODV and the scalable video coding provides an efficient platform for supporting rate-adaptive video streaming.

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1. Introduction

A mobile ad-doc network (MANET) consists of a collection of mobile nodes that communicate in a multi-hop way without a fixed infrastructure. MANETs are very versatile and appropriate to be used in many scenarios due to the infrastructure-less and self-organized characteristics. However, they have different limitations such as bandwidth-constrained, variable capacity links and energy-constrained operation. Moreover, routes may include multiple hops because communications need to use intermediate nodes as routers in order to communicate with nodes that are out of its transmission range. This dynamic topology of nodes causes frequent link failures and high error rates, so it makes it difficult to maintain the desired quality of service (QoS) in the network. Additionally, due to the fact that the wireless channel is shared among neighbour nodes and that network topology can change as nodes move, the transmission of time-sensitive data (e.g. video packets) is made more difficult [1]. Furthermore, with the prevalence of multimedia applications, it has become very necessary for MANETs to have an efficient routing and QoS mechanisms to support these applications. Thus, traditional best-effort protocols are not adequate. This is because multimedia applications require the underlying network to provide certain guarantees that are manifested in the support of several important QoS parameters such as bandwidth, delay, jitter and packet loss rate.

We propose in this paper a cross-layer strategy for adaptive video streaming in MANETs based on the estimation of the available network resources and the subsequent adaptation of the transmission rate. The main contribution of this work is the development of a comprehensive QoS routing protocol, named AQA-AODV (adaptive QoS-aware for ad hoc on-demand distance vector). Our approach includes novelty features. In addition, we propose the use of AQA-AODV in conjunction with the scalable video coding (H.264/SVC) [2] as a realistic solution for supporting rate-adaptive video streaming.

AQA-AODV is a modified and enhanced version of the routing protocol AODV (ad hoc on-demand distance vector) [3]. More precisely, we have introduced into the original AODV protocol an adaptive feedback scheme and two mechanisms: one for the estimation of the available bandwidth in each node and the other for the prediction of the consumed bandwidth for a route of multi-hops. In addition, some QoS fields are added to the AODV control packets and the routing table. The Generalized MANET packet/message format [4] has been considered in the definition of the routing messages of AQA-AODV. Therefore, although our protocol has been designed as an

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enhancement of AODV, the proposed algorithms and the new packet fields can be integrated into AODVv2 [5] in order to provide QoS mechanisms to this routing protocol.

On the other hand, scalable video coding is a flexible coding technique where the video streams are composed of a base layer and one or more enhancement layers, which may enhance the spatio-temporal resolution and/or quality of the base layer. Based on such scalable-layered structure, a video stream can be easily adapted to meet constraints imposed by devices and networks adding or removing SVC layers. For an effective SVC adaptation, AQA-AODV provides a cross layer approach in order to estimate the available bandwidth. Such information is later sent to the video application to adjust the amount of layers that can be transmitted. This network-adaptive strategy avoids congestion and a large number of dropped packets. Congestion and losses are worse than transmitting video using low data rate. This design concept is consistent with the current paradigm, known as application-oriented paradigm, which involves a new strategy of development of solutions for MANETs where application requirements are identified before the development of the technical solutions [6].

We conducted a performance evaluation of our proposed solution in order to demonstrate that it is an effective system for providing video streaming services over MANETs. In particular, the evaluation focuses on the analysis of traffic metrics, such as packet losses and end-to-end delay as well as metrics specifically related to video quality (such as PSNR and decoded frame rate). We have developed a novel simulation framework (named SVCEval-RA [7]) to perform the simulation experiments, which represents an additional contribution of this paper. This software tool integrates the network simulator NS-2 [8] with external tools for analysing H.264/SVC video streams. Our framework provides an efficient platform in order to perform simulation studies that involve rate-adaptive video streaming. The experimental results show that the combined use of AQA-AODV and scalable video coding provides an efficient system for supporting adaptive video streaming where video application can adapt its bit rate according to the available bandwidth. Consequently, the quality of the received videos has been significantly improved.

The rest of the paper is organized as follows. First, we introduce related works on QoS routing for MANETs in Section 2. Then, in Section 3 we describe the impact of the channel capacity and the packet forwarding over delay and packet loss in wireless ad hoc networks. In addition, we briefly review the main characteristics of AODV and QAODV protocols. In Section 4 we present a more detailed explanation of the main components of AQA-AODV protocol. Section 5 gives a brief introduction to the scalable video coding. The results of the performance evaluation of the proposed QoS-aware routing protocol are described in Section 6 and finally, we present our conclusions in Section 7.

2. Related work

Video transmission over wireless ad hoc networks has been discussed during last years and it has become an attractive topic in many papers and research works. However, actually the provision of video streaming services over MANETs is still a challenging task due to the difficulty of meeting certain levels of QoS. Hence, several approaches have been proposed to provide QoS in mobile ad hoc networks, which can be classified according to the layer they operate. Some recent approaches for providing QoS in MAC layer can be consulted in references [9–12] and in the survey [13]. Regarding the QoS solutions for network layer, most of the QoS routing protocols are the extensions of existing best-effort routing protocols. Numerous reactive and proactive QoS routing protocols have been proposed for MANETs recently. Nevertheless, in this paper focus is on reactive QoS routing protocols and mainly those solutions based on the well-known AODV routing protocol. For example, Su et al. [14] and Zhen and Wenzhong [15] proposed some approaches which use AODV as routing protocol within a TDMA (time division multiple access) network. However, TDMA has a less efficient controlled access scheme because of the lack of infrastructure and the peer-to-peer nature of ad hoc networks. Other QoS routing protocols are based on the Internet draft [16] (called QAODV) which describes the format and extensions to provide QoS support in AODV. Some approaches of this kind are described in references [17–21]. They are based on the model of admission control of QAODV without any mechanism of feedback. Therefore, the source cannot know the available resources of the network. Moreover, the initial QoS conditions are not maintained after link failures due to the lack of a suitable route recovery algorithm. Other solution based on AODV is the RBRP protocol proposed by Tabatabaei et al. [22]. They extend the route discovery process using the Q-learning strategy to select a stable route to enhance network performance. This technique improves performance achieved with AODV through an enhanced route selection based on hop count, bandwidth, power of battery and speed of mobile nodes. However, this proposal does not improve the performance achieved by other QoS routing solutions because of it does not take into consideration some constraints inherent in the mobile ad hoc networks (e.g. the mutual interference of the nodes). This fact leads an inaccuracy estimation of the available bandwidth. On the other hand, Quin et al. [23] proposed a solution called ORAC, where a cooperative communication strategy (opportunistic routing) and an admission control scheme are integrated to provide certain QoS for different types of multiple flows. Despite this approach achieves improvements in terms of throughput, average delay and energy consumption, its performance is significantly degraded in mobile scenarios.

Although numerous research works have been mainly focused on the network layer, video delivery can be improved through cross-layer techniques since some functions cannot be assigned to a single layer. In this sense new solutions involving several abstraction layers have been proposed [24–27]. Hence, it is worth considering cross-layer routing solutions, which can extract useful information from other networks layers. For instance, video awareness could offer new mechanisms to improve video transmissions, such as bandwidth adaptation, intra-frame prioritization or even algorithms that react to the play-out buffer state, obviously at the expense of adding complexity. This content-awareness leads to other solutions based on enhanced video coding. These solutions can support adaptive video streaming schemes using versatile techniques, such as scalable video coding (SVC) [28,29] or multi-description coding (MDC) [30,31]. In fact, cross-layer solutions can provide enough information to upper layers in order to adapt video rate accordingly increasing the quality of video streaming services while the bandwidth efficiency is achieved. Despite the complexity of providing hard QoS for multimedia applications over MANETs, there are still many options to improve video streaming quality, through holistic approaches that involve routing, transport and application layers.

3. Background

Providing quality of service support for wireless ad hoc networks is very challenging, due to many factors, e.g. the use of a shared communication medium. Difficulties lie in the limitation of the maximum achievable throughput caused by the fact that nodes cannot simultaneously access the medium. More specifically, when a node is transmitting a packet, neighbour nodes within its interference range (IR), have to keep silent. This fact degrades the wireless data rate. Even more, when a transmission is established, the nodes must cooperate to forward the packets through the network, which means that the available throughput on each host is limited not only by the access channel, but also by the forwarding load. Therefore, network

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