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Cross-layer optimized wireless multicast for layered media ☆

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A B S T R A C T

This paper discusses the maximization of user-perceived quality of layered media in wireless networks. We present a system model and an optimization framework for such networks assuming: (i) the data rates are nested, (ii) the media is multicast, (iii) layered and (iv) the media layer information is available in lower network layers based on cross-layer information. In order to show the general applicability of the proposal, different maximization targets and algorithmic solutions are presented.

1. Introduction

In this paper we show how the user-perceived quality of media can be maximized in wireless networks. It is assumed that (i) a single, shared channel is used for multicast traffic in a cell, (ii) multiple data rates are available using different channel coding and modulation and (iii) terminals closer to the Access Point (AP) can receive multicast using both higher and lower data rate transmission, while terminals farther from the AP can receive lower data rate transmission only. This latter property is referred to as nested data rates (see Fig. 1). It is also assumed that the media is multicast, layered and the media layer information is available in lower network layers based on cross-layer information. We present a system model and an optimization framework in order to provide maximum user-perceived media quality in such networks. The goal can be achieved by sending the media layers at the optimal data rate. The presented model is based on, but not restricted to IEEE 802.11 Wireless Local Area Networks (WLANs). In the optimization framework, different maximization targets and algorithmic solutions are presented.

The user-perceived quality of the media depends on the received number of layers and the quality properties of the layered media. The layered media to be multicast typically consists of a base and a number of additional enhancement layers. Each additional layer provides progressive quality improvement. The larger the number of received layers is the higher the perceived quality becomes. There are available codecs providing such layered media stream like Advanced Audio Coding – Bit-Sliced Arithmetic Coding (AAC-BSAC) [1] and Scalable Speech Audio Codec (SSAC) [2] for audio and H.264/MPEG-4 Advanced Video Coding (AVC) [3] and its extension, the Scalable Video Coding (SVC) [4,5] for video. These media codecs provide Fine Grade Scaling (FGS). With FGS continuously increasing quality can be provided resulting in dozens or even hundreds of media layers in case of audio [2] and practically more than 30 in case of video.[2]

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[2] E.g, taking only two levels of spatial scalability, five of temporal and three of SNR results 30 layers.

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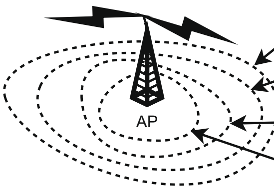

Fig. 1. Illustration of nested data rates of WLAN 802.11b networks.

In order to take advantage of the media's scalability, the media layer information has to be available not only at the application layer, but also at lower network layers using cross-layer information forwarding techniques. E.g., the Layer Independent Descriptor (LID) concept [6] proposes the Differentiated Services Code Point (DSCP) in Internet Protocol (IP) packet headers to indicate the importance of the packets to achieve graceful quality control.

The (cross-layer based) quality control is more important in wireless access networks, where users may perceive different channel quality due to their distance from the AP and wireless phenomena (like multipath fading, etc.), in other words *receiving capability* of the users. Therefore, the received media quality should be optimized per user. This optimization task raises difficulties for current WLAN standards. Today in WLAN, only one data rate is used for multicast delivery, which data rate is mostly the lowest and provided by the most robust modulation. This technique does not differentiate the users, but ensures that all users can receive all of the data. The data rate of the transmission is fixed and the possibility of changing the data rate per packet is not used for multicast, because there are no quality feedback and processing functions defined. This insufficiency of the current delivery method limits deploying efficient multicast schemes in wireless access networks like WLAN.

The existing multicast approaches [7] do not take the advantage of nested data rates existing, e.g., in WLAN networks, because these approaches were developed originally for wireline technology. In networks having nested data rates, all lower data rates are available for a user in conjuction with potential additional higher data rates. (See Fig. 1 for illustration in case of WLAN 802.11b networks.) In such networks if the receiving capability of the users is known (based on some reporting technique), the playblack quality of the layered media can further be improved and tailored to the individual receiving capability of the users.

In this paper a system model is presented for multicast optimization and a proposal is given to complete the current WLAN standard according to this model. Note, that the proposed solutions can be implemented in any other network providing nested data rates. Besides the system model, three possible optimization targets and solutions are presented. Since the exact solution of two targets is NP-complete, heuristics are also given. We show that the heuristics are good enough for the most common case of many layers.

The rest of the paper is organized as follows. First, an overview of the related work is given. Then a general system model for multicast optimization is presented in Section 3, which allows the operators to maximize the user-perceived quality of media delivery meanwhile optimizing the channel usage of wireless network. The system model is introduced through an example of IEEE 802.11 WLAN [8,9] networks. Separately from the system, different targets of the optimization task and algorithmic solutions are presented in Section 5. The performance of the proposed solutions is analyzed in Section 6. Finally Section 7 summarizes the paper.

2. Related work

The existing multicast approaches [7] come from the wireline technology. In Single Stream Adaptive Approach (SSAA), a single version of the media is transmitted for all users. This approach is typical in today's wireless networks. In Replicated Streams Approach (RSA), different quality versions of the media are sent out by the media server and users having higher bandwidth sign up for a higher quality of the media. Each version forms an independent stream and multicast group. This method is bandwidth wasting because of multiple and parallel transmissions of the media. To overcome the drawback of RSA, the Layered Streams Approach (LSA) can be used, where different layers of the media are sent to different multicast groups. With receiver-driven controlling methods [10–12], each user can decide to which groups (layers) they sign up. This approach eliminates the redundant transmission, meanwhile optimizes the perceived quality at the expense of some application layer overhead [13]. RSA and LSA is applicable in wireless networks as well. However, since current WLAN standards do not support information on receiving capability, both approaches have to use the most robust transmission rate, i.e. the slowest, to reach all users in the cell. Hence, it is possible that not all quality versions (RSA) or media layers (LSA) fit in the channel capacity due to the higher bandwidth demand. Nevertheless LSA utilizes the layered structure of the media in a more efficient way, running out of capacity is a risk for both solutions. Another way how RSA and LSA can be adopted to wireless networks is proposed in [13]. Different data rates can be considered as individual access networks. That is, all layers and quality versions has to be sent to all access networks. This solution still transmits redundant data and overload the network. Instead of a receiver-driven method we propose a centralized. We aim to optimize the overall performance of the system regarding the user-perceived quality. A simple way to realize such an optimization concept could be to use a table lookup mechanism [14]. From a