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Cognitive radio assisted quality compensation for scalable video multicast in cellular networks

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ABSTRACT

Existing multicast schemes always employ the scalable video coding (SVC) to accommodate heterogeneous channel conditions. Although this method achieves a high spectral efficiency, it will lead to serious *quality imbalance* problem, i.e., the viewers who hold a better link conditions can obtain high video quality, but the viewers with bad reception conditions can only receive the video with poor quality. In this paper, we propose a novel Cognitive Radio Assisted Quality Compensation (CRAQC) scheme for enhancing the video quality of bad reception viewers. In CRAQC, the bad reception viewers can obtain from the good reception viewers the video content they cannot receive directly from the base station using cognitive relay links. One novel and promising design of the proposed scheme is that it considers a cooperative transmission style in relay process, in which viewers with the same relay content can simultaneously broadcast this content in the same channel, and therefore achieve the benefits of space diversity to the receiver. Through extensive simulations, we demonstrate that CRAQC is able to significantly improve the video performance of the bad reception viewers.

1. Introduction

Traditional mobile networks were initially designed for unicast services, and may waste radio resources by transmitting the same content in multiple copies to different nodes. With multicast, higher resource utilization would however be possible. Multicast service is therefore, a significant part of the current mobile services. Examples include the Multicast/Broadcast Service (MBS) over the WiMAX [1], the enhanced Multimedia Broadcast/Multicast Service (eMBMS) within the LTE [2], the Digital Video Broadcasting services (e.g., DVB-T, DVB-H) defined in European Telecommunication Standard (ETS) [3], and the MediaFLO presented by Qualcomm Corporation [4].

There is a well-known problem to be addressed to effectively deploy reliable and flexible mobile multicast services. In mobile networks, all frames with multicast Receiver Address (RA) are transmitted at a rate selected from a basic rate set. In order to guarantee coverage over all associated nodes, the transmission rate is typically fixed to one of the low basic rates. This limits the rate at which multicast data can be sent, for example, high-definition video is hard to sent via multicast. To address this problem, scalable video multicast (SVM) technology has been proposed [5,6]. In SVM, video is encoded into one base layer (BL) and several enhancement layers (ELs) [7]. The BL ensures the basic video quality of all nodes

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and each additional EL further enhances the quality of the video.

In order to adjust the video rate commensurate to the node's channel conditions, the BL and ELs are often transmitted using different modulation coding schemes (MCSs). In this manner, however, only the viewers with good reception conditions can receive more layers from the base station (BS), and therefore can obtain a desirable perceived video quality. For viewers who locate in the cell boundary or the high fading regions, the perceived video quality is seriously suppressed due to the bad reception conditions.

To improve the perceived video quality of the bad reception viewers, in this paper, we propose a novel Cognitive Radio Assisted Quality Compensation (CRAQC) scheme, in which the viewers with bad video qualities can obtain the video content they cannot receive directly from the BS from the viewers who have good reception conditions using cognitive relay links (see Fig. 1). To cost-effectively provide services and applications, in CRAQC, the BS is able to adaptively selects the relay nodes from the relay candidates and determines the relay scheme and transmission rates based on the instantaneous network conditions. Additionally, to enhance the relay efficiency, we consider a multiuser cooperative relay style [8]. Specifically, to relay an EL content, the viewers who successfully receive this EL from the BS will constitute a cooperative set. In the relay process, the viewers in this set can be scheduled to simultaneously broadcast this EL content in the same relay channel. In this way, a cooperative set can be seen as a super user equipped with multiple antennas, and then the gains of space diversity can be achieved.

In summary, the major contributions of this paper can be summarized as follows:

- We study quality imbalance problem in scalable video multicast services in cellular networks and present a novel cognitive radio assisted video quality compensation solution to improve the video quality of the bad reception viewers. Our solution can also be used to enhance the performance of cell-edge nodes in any wireless applications.
- We propose an easily implemented spectrum acquisition scheme, an adaptive relay rates scheduling scheme, an optimal relays selection scheme and a cooperative transmission mechanism in the proposed quality compensation scheme for cost-effectively providing services and applications.
- We systematically evaluate the performance improvement attributed to several important factors, including the node density and the node transmission power. Simulation results demonstrate that the CRAQC can significantly improve the video quality of cell-edge nodes in mobile multicast services.

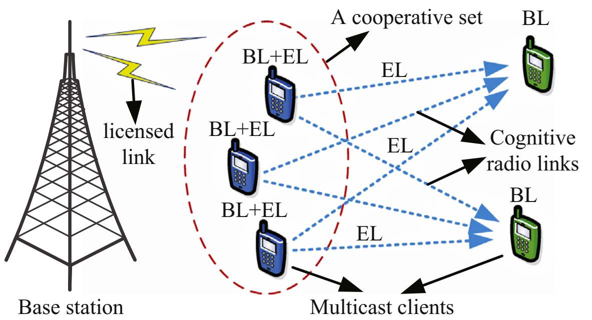

Fig. 1. Illustration of the CRAQC scheme.

The remainder of this paper is organized as follows. In Section 1.1, we briefly review the related works. In Section 2, we introduce the system models. The framework of the CRAQC is given in Section 3. The problem formulation for optimal relay rate scheduling and the corresponding low-complexity algorithms are given in Section 4. The video trace driven simulation results are shown and discussed in Section 5. Finally, we conclude this paper in Section 6.

1.1. Related works

Quality compensation for bad reception viewers in fixed-rate video transmission services has been studied by several research groups in the past. In [10], a unified cellular and ad-hoc network (UCAN) architecture has been proposed for enhancing cell throughput in unicast system. To achieve a higher overall video quality in the architecture, in UCAN, nodes with bad channel condition can select nodes with better channel condition as their "helpers" to receive data from the BS by using the IEEE 802.11 links. The similar mechanism can also be employed to improve the video performance in fixed-rate multicast services. The related studies can be found in [11–13].

In [14] and [15], Sha and Yang et al. further extend this idea to the scalable multicast services. In Sha's work, the video is encoded into multiple layers. To improve the perceived video quality of cell boundary viewers, an ad-hoc video forwarding scheme is proposed, in which the viewers far away the BS can obtain the video content from their neighbors close to the BS that they cannot receive directly from the BS by using the IEEE 802.11 links. However, due to the limited transmission range of the IEEE 802.11 links, the ad-hoc based quality compensation scheme is only suitable for use in dense network.[1]

Compared with the above works, our work mainly differs in the following four aspects:

1. We use the cognitive radio links rather than 802.11 links to relay the video content. Compared with 802.11 link, the cognitive relay link has more flexibility in the channel and the transmission power.
2. We consider a cooperative transmission style in our scheme, all nodes who successfully receive an EL can simultaneously broadcast this EL to those who needs help via cognitive radio links. In this manner, the reception condition (received SNR) of the bad reception nodes in relay process is expected to be greatly improved, and the transmission range limitation problem held by the

[1] Notice the maximum transmission range of the IEEE 802.11 links does not exceed 100 m. In a sparse network, the node who needs help is hard to find the helpers within its transmission range.