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Adaptive and ubiquitous video streaming over Wireless Mesh Networks

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Abstract In recent years, with the dramatic improvement on scalability of H.264/MPEG-4 standard and growing demand for new multimedia services have spurred the research on scalable video streaming over wireless networks in both industry and academia. Video streaming applications are increasingly being deployed in Wireless Mesh Networks (WMNs). However, robust streaming of video over WMNs poses many challenges due to varying nature of wireless networks. Bit-errors, packet-losses and burst-packet-losses are very common in such type of networks, which severely influence the perceived video quality at receiving end. Therefore, a carefully-designed error recovery scheme must be employed. In this paper, we propose an interactive and ubiquitous video streaming scheme for Scalable Video Coding (SVC) based video streaming over WMNs towards heterogeneous receivers. Intelligently taking the benefit of path diversity, the proposed scheme initially calculates the quality of all candidate paths and then based on quality of path it decides adaptively the size and level of error protection for all packets in order to combat the effect of losses on perceived quality of reconstructed video at receiving end. Our experimental results show that the proposed streaming approach can react to varying channel conditions with less degradation in video quality.

1. Introduction

In recent years, with the dramatic improvement on scalability of H.264/MPEG-4 standard and growing demand for new multimedia services have spurred the research on scalable video streaming over wireless networks in both industry and academia. Robust streaming of video over wireless networks is fraught with many challenges including bit-errors, packet-losses and burst-packet-losses due to varying nature of wireless networks. In the case of Wireless Mesh Networks (WMN), we have multiple challenges. These challenges are diverse nature of topology, non existence of fixed infrastructure, and due to varying number of hops it becomes more difficult to maintain

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the required delay and quality of service (QoS). Since WMN is more error prone than classic wireless networks we need to address all possible error protection methods both at server and receiver ends as we can not rely on middle infrastructure. The errors in WMN severely influence the perceived video quality at receiving end. Wireless transmission at high packet rates is often characterized by burst-packet-loss behavior, i.e. if one packet is lost there is more chance that consecutive packets will also be lost. The effect of high error rates can be more devastating for streaming of compressed video such H.264/MPEG-4 SVC, which uses motion-compensated prediction. Although, motion-compensated prediction can achieve high compression efficiency, but it is not designed for streaming over error-prone channels. In motion-compensated based coding, the video sequence consists of two types of video frames, intra-frames (I-frames) and inter-frames (P or B-frames). The intra-frames are encoded by only removing spatial redundancy present in the frame. P-frames are encoded through motion estimation using preceding I or P-frames as a reference frame. B-frames are encoded bi-directionally using the preceding and succeeding reference frames. This poses a severe problem called error propagation, where the errors due to packet loss in a reference frame propagate to all of the dependent frames leading a severe degradation in perceived video quality that can be long-lasting. Thus carefully-designed error recovery scheme is essential for providing reliable and robust video streaming.

Many approaches dealing with the error recovery have been proposed in literature such as error resilience, error concealment, forward error correction (FEC) and automatic repeat request (ARQ). However, none of these approaches can fulfill all quality criteria by itself. A scalable bit-stream of video consists of a base layer and one or more enhancement layers. The base layer provides a basic level of video quality and is decodable independently of the enhancement layers. While on the other hand, the enhancement layers serve only to refine the base layer quality and are not useful alone. Thus, the base layer represents the most important part of video data, which makes the performance of streaming applications that employ layered representation sensitive to losses of base layer packets. Therefore, the base layer needs to be protected more strongly as compared to enhancement layers. However, assigning unequal error protection to scalable video is more complex and difficult than non-scalable video due to layered structure.

In this paper we propose and implement a hybrid error control scheme for Scalable Video Coding based streaming over WMNs which is a combination of adaptive unequal error protection, adaptive packet size assignment and path diversity. The work presented in this paper is an extension of Kormentzas (2010). The work in Kormentzas (2010) focuses on the fixed packet size (FPS) with fixed unequal error protection (FUEP). In this work, we extend the work in the following three directions.

1. Fixed packet size with adaptive unequal error protection (FPS + AUEP).
2. Adaptive packet size with fixed unequal error protection (APS + FUEP).
3. Adaptive packet size with adaptive unequal error protection(APS + AUEP).

It is important to mention here that prior work in the field of ad hoc networks has extensively taken advantage of the path diversity available through layered video coding or Multi Description Coding (MDC). The key question is how to utilize this path diversity more efficiently. In our proposed scheme the nodes are able to send periodically their state information to all of their neighbor nodes. Thus, based on node's state information, such as delay, jitter, loss rate and throughput, first the source node calculates the quality of all candidate paths using gray relational analysis (GRA). Then based on quality of path, it decides adaptively the size and level of error protection for all packets in order to combat the effect of losses on perceived quality of reconstructed video. The proposed scheme is implemented using HD/SD SVC-based video streams on the real platform rather than using any simulation tool as explained in Section 6. The performance comparisons of proposed scheme with some other existing schemes were performed. The video quality is measured based on most widely used metrics such as peak signal to noise ratio (PSNR) and Video Quality Model (VQM). The VQM tool (Wolf, 2006), which implements the International Telecommunication Unit (ITU-T) J.144 recommendation (Objective perceptual video, 2003) compares the original video stream with the reconstructed video stream using television model and reports a metric between 0 and 1. Lower VQM scores correspond to better video quality. After a series of repeatable experiments on test-bed, our results show that the proposed streaming approach can react to varying channel conditions with less degradation in video quality.

Rest of the paper is organized as follows: Section 2 describes the related work. Brief overview of scalable video is provided in Section 3. The proposed path selection and adaptive unequal error protection with adaptive packet size assignment schemes are explained in Sections 4 and 5 respectively. An overview of test platform and experimental results are presented in Section 6. Finally, this work is concluded in Section 7.

2. Related work

In this section we briefly review the previous work on the error control for video streaming. Basically the error control schemes can be classified into four categories e.g. error resilience, error concealment, forward error correction and automatic repeat request. The first type involves the design of smart encoders which attempt to limit the scope of the visual damage caused by lost data. The second type deals with designing of smart decoders, which attempt to hide the lost data using received data. The third type involves adding redundant data while the last one involves retransmission of lost data. The error control for Scalable Video Coding has attracted much attention due to its importance and many studies have been proposed so for. As discussed in Section 3, in scalable video bi-stream different layers have different importance so they should be protected unequally according to their importance. However, assigning unequal error protection to scalable video is more complex than non-scalable video due to layered structure of SVC.

Many studies have been conducted to tackle the problem of Unequal Error Protection (UEP) for SVC by appropriate consideration of the various frame types such as in Ang et al. (2003), Marx and Farah (2004), Fang and Chau (2005) and Helle et al. (2013). Some researchers have focused on applying