Effective Broadband Video Streaming during Wireless Vertical Handovers

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***Abstract*— While video streaming, vertical handover between heterogeneous wireless networks remains a scarcely addressed problem. Broadband Video Streaming (BVS) with adaptive packet retransmission promises better video quality during a Hard Handover (HHO) than both raw UDP transport and traditional congestion-controlled streaming, making it attractive to mobile video streaming services. It achieves this by distinguishing between high congestion and poor channel conditions, the latter of which an HHO induces, and by prioritized retransmission according to picture type.**

I. Introduction

An important difference between video streaming delivery to mobile devices and broadband access is the possibility of vertical handovers, which can cause disruption to real-time video streaming, due to factors such as: route setup delay; signalling message overhead and processing time; and packet loss. This paper proposes a lightweight form of video transport based on negative acknowledgments, which, during video streaming of catch-up TV, aims to improve delivered video quality over that of raw UDP transport and traditional congestion controllers such TCP-Friendly Rate Control (TFRC) [1]. The Broadband Video Streaming (BVS)-adaptive (A) scheme is simulated across the delivery path from a remote server on an unmanaged wired core network to either an IEEE 802.11 access point or an IEEE 802.16e (mobile WiMAX) base station (BS). An underlying IPTV content delivery network is assumed to reduce the video delivery path length, which in turn reduces the latency of the single negative acknowledgments employed.

BVS-A, by virtue of its adaptive structure, is designed to react both to traffic congestion and to poor channel conditions. It does this by selecting packets by their video picture type according to traffic conditions. Consequently, when a vertical handover occurs, BVS-A can react as if poor channel conditions have occurred, rather than assuming traffic congestion. By contrast, TFRC has only one mode of response, reacting to traffic congestion, which arises as a result of its provenance as a wired Internet congestion controller. Nevertheless, TFRC is a standardized controller that has been widely adopted. For example, in [3] it was tested as a controller for streaming over a Long Term Evolution (LTE) link.

II. Adaptive Broadband Video Streaming

The BVS-A scheme introduces a single negative acknowledgment (NACK) to User Datagram Protocol (UDP) transport. At the receiver, a record is kept of packet sequence numbers and if an out-of-sequence packet arrives a NACK is transmitted to the sender. The video source prevents transmission from its input buffer until a single retransmission of the missing packet in the sequence has taken place. Further retransmissions do not take place, because waiting packets could be delayed and because the failure of one retransmission may indicate continuing poor channel conditions across the broadband wireless link. During prioritized operation a decision is made to resend a video packet according to the picture type of the packet that has been lost, reflecting the importance to the reconstruction of the video stream judged by that packet's picture type.

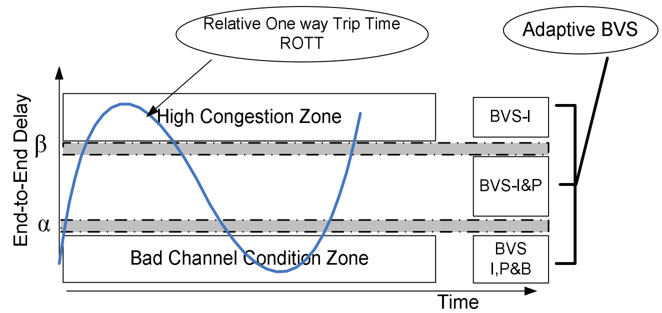


Fig. 1. The Spike scheme applied to BVS-A.

BVS-A has been applied according to the Spike scheme [3]. In the Spike scheme, a peak or spike in the Relative One-way Trip Time (ROTT) indicates the presence of congestion. When the ROTT passes above a given threshold, packet loss is definitely from congestion. When it passes below a threshold, it is assumed to be definitely from wireless channel conditions. In Fig. 1, in the bad channel zone, packets from all picture types are re-transmitted when necessary, in order to reconstruct the video sequence. However, if there is limited congestion and moderate problems within the wireless channel then only intra-coded I- and inter-coded P-picture packets are re-sent in order to reduce delay arising from retransmissions. If congestion increases then within the high congestion zone, only I-picture packets are re-transmitted to avoid further adding to the congestion. B-picture packets can be neglected as they have no effect on predictive decoding. I-pictures are always re-transmitted in whatever zone as they affect the reconstruction of the rest of a Group of Pictures (GoP).

III. Evaluation

In simulations, 35.5s of the reference *Paris* clip were variable bitrate encoded using an H.264/AVC (Advanced Video Coding) codec with Common Intermediate Format @

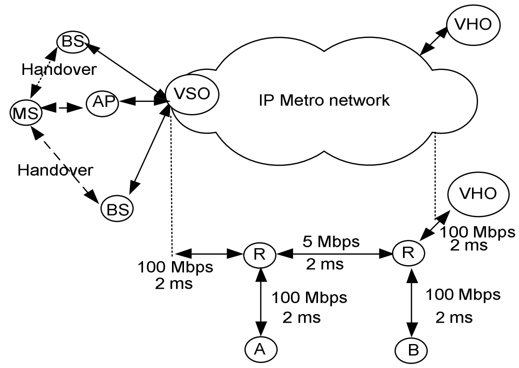


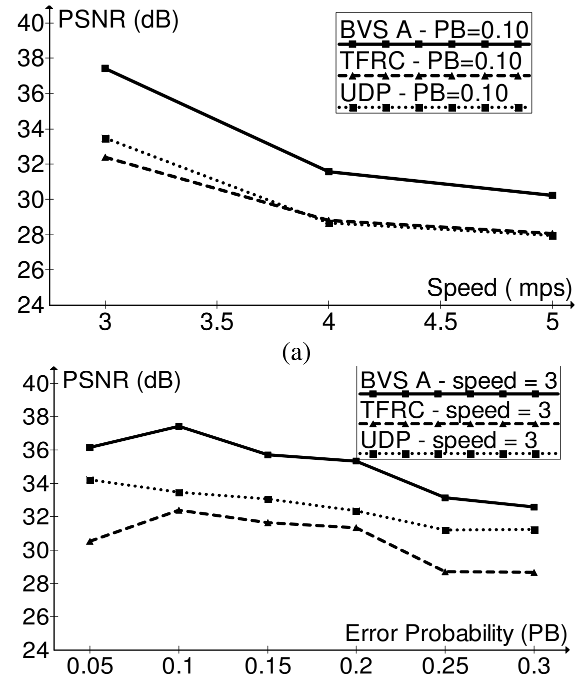
Fig. 2. Video streaming scenario with dual handovers as video is streamed from the VHO.

30 Hz. The GoP structure was IBBP… with an intra-refresh rate of 15.

A Gilbert-Elliott two-state channel model modeled error bursts during fast fading. The probability of remaining in the good state was set to 0.95 and of remaining in the bad state was 0.94, with both states modeled by a Uniform distribution. The packet loss probability in the good state was fixed at 0.01 and the bad state probability (PB) was made variable. The WiMAX PHYsical layer settings were 5 ms Time Division Duplex (TDD) frame, 16-QAM ½, guard band 1/8, maximum packet length 1 kB, raw data-rate 10.67 Mbps, and range 1.0 km. Buffer sizes were set to 50 packets. Vertical handover was modelled with the NIST IEEE 802.21 module for the ns-2 simulator, which is tied to the IEEE 802.11b model built into ns-2 operating at 11 Mbps. (Available from http://w3.antd.nist.gov/seamlessandsecure/ [accessed Jul. 2010].)

In Fig. 2's dual handover scenario, a remote server at the video head office (VHO) streamed video over the IP network to the video serving office (VSO) in the content delivery network, while node A sourced to node B constant bitrate (CBR) data at 1.5 Mbps with packet size 1 kB and sank a continuous TCP FTP flow sourced at node B. Node B also sourced an FTP flow to the BS and CBR data at 1.5 Mbps with packet size 1 kB. The MS moved in parallel to the first BS then to the wireless access point (AP) and on to a second WiMAX BS, each of which transmitters were separated by 0.825 km.

From Fig. 3(a), one observes a decline in objective video quality as the speed of the user increases. The BVS-A quality remains good (above 30 dB) throughout, whereas TFRC offers less than raw UDP at the same bad-state channel setting (PB = 0.10). In fact, TFRC's sending time for the entire clip is longer than UDP or BVS-A, as it reacts to congestion by lengthening the inter-packet gap. At a speed of 3 mps, Fig. 3(b), one sees the response as channel conditions worsen. That this is not a monotonic decline is due to the type of packets that happen to be lost, as Fig. 4 illustrates. Recall that I-pictures generate more packets than P- and B-pictures. While I-picture packets are dropped in a similar ratio to the other types with UDP transport, TFRC's mode of control actually discriminates against I-pictures leaving them exposed to the channel for longer periods, especially during handovers. Consequently, video quality is reduced.



(b)

Fig. 3. Video quality (Y-PSNR) of BVS-A for (a) varying mobile device speeds (b) different channel conditions.

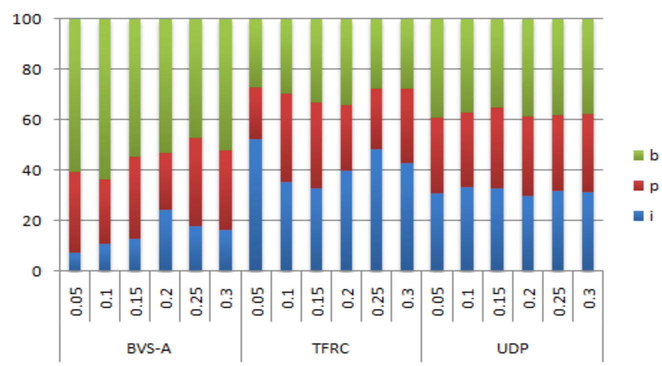


Fig. 4. Frame type packet loss percentage for different channel conditions (PB = 0.05 ... 0.3) with a mobile speed of 3 mps.

IV. CONCLUSION

Adaptive broadband video streaming, by preserving anchor frames during handover, improves upon traditional congestion control, which seems ill-suited to realistic scenarios when handovers take place. The next step is to provide selective encryption for the forward video stream and one-time pad-based authentication for NACKs.

REFERENCES

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