Versatile IPTV for Broadband Wireless with Adaptive Channel Coding

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***Abstract*—This paper proposes a versatile IPTV video-streaming scheme that can provide high-quality unicast with the aid of repair packets but still support multicast without repair packets. Adaptive, application-layer channel coding for broadband wireless, compared to a fixed-rate code, reduces the bitrate overhead by several percent. Data-partitioned source coding without periodic I-pictures is adopted, making for a practical broadband wireless streaming scheme.**

I. INTRODUCTION

If IPTV is to support a mobile service it must address the much increased risk of wireless channel errors. In developing a robust mobile unicast service [1] suitable for time-shifted TV, we noticed that the research literature tends to propose either unicast solutions or multicast solutions but not both together. Clearly, compared to unicast, multicast improves bandwidth efficiency by sharing video packets delivered through a network. However, unicast streaming permits individualized error protection for each stream, thus avoiding the principal detraction of multicasting. With multicast streaming there is a risk of a feedback implosion at the server, an overload of network resources due to the attempts of many receivers trying to send repair requests for a single packet. A number of approaches exist to avoid this implosion effect such as randomized timers, local recovery whereby receivers can also send repair packets, and hierarchical recovery. Nevertheless, while such approaches are effective, providing reliability without implosion, they can sometimes result in significant and unpredictable delays, making them unsuitable for real-time applications.

Instead, in this paper we ask whether the same protection scheme can be employed for unicast and multicast by turning automatic repeat requests (ARQs) for repair packets on and off according to the casting mode. By testing the same adaptive, application layer (AL) forward error control (FEC) scheme for both unicast and multicast one can judge what the impact on video-quality penalty is from turing off repair packets in multicast mode. A related question is what level of fixed AL-FEC is necessary to improve video quality, compared to an adaptive scheme that responds to wireless channel conditions. Of course, in a short paper we are not able to show all possible objective video qualities (PSNR) but it is still possible to say that the fixed-rate AL-FEC datarate overhead is about 5% more compared to an adaptive FEC scheme, as simulated results for IEEE 802.16e (mobile WiMAX) demonstrate in this paper.

II. METHODOLOGY

Both the unicast and multicast modes of the scheme use adaptive rateless channel coding for AL-FEC. In our scheme, the probability of channel byte loss (*BL*), based on continuous serves to predict the amount of redundant data to be added to the payload. In an implementation, *BL* is found through measurement of channel conditions. As channel measurement is known to be inaccurate, in simulations, 5% normally distributed noise was added to the estimate of *BL*. If the original packet length is *L*, then the redundant data is given simply by

$$R = L\times BL+(L\times BL^2)+(L\times BL^3)\ldots \qquad (1)$$
$$= L/(1-BL) - L.$$

The following statistical model [2] was used to model the repair probability of the Raptor variety of rateless channel coding :

$$P_f(m,k) = 1 \quad \text{if } m < k$$
$$= 0.85 \times 0.567^{m-k} \quad \text{if } m \geq k \qquad (2)$$

where $P_f(m,k)$ is the decode failure probability of the code with k source symbols if m symbols have been successfully received. If a packet cannot be decoded despite the provision of redundant data then in the unicast mode of the scheme (not in the multicast mode) extra redundant data are added to the next packet. It is implied from (2) that if less than k symbols (bytes) in the payload are successfully received then a further k - m + e redundant bytes can be sent, 'piggybacked' on the next packet, to reduce the risk of failure. In simulations, e was set to four, which if the extra data in the repair packet successfully arrives, reduces the risk of packet loss to 8.7%, because of the exponential decay of the risk that is evident from equation (2).

The tests were performed on the reference *Paris* (moderate spatial-coding complexity) and *Football* (high temporal coding-complexity) video sequences encoded in Common Intermediate Format (CIF) @ 30 Hz. In the H.264/AVC (Advanced Video Coding) codec used, data-partitioning was enabled, such that every slice was divided into three separate partitions according to their importance in reconstruction at the decoder. The GoP structure was IPPP…, i.e. one initial intra-coded I-picture and all predictively-coded P-pictures. By default, 2% intra-refresh macroblocks (MBs) were randomly inserted within each P-picture to restrict temporal error propagation. Constrained Intra Coding (CIP) was turned on to ensure independent decoding of partition B. For comparison, Constant Bit Rate (CBR) streaming was tested at two different rates.

The video stream was simulated to be transmitted from a WiMAX base station to an IEEE 802.16e mobile station (MS) and, to provide sources of traffic congestion, a permanently available FTP source was introduced with TCP transport to a second MS. Likewise, a CBR source with packet size of 1000 B and inter-packet gap of 0.03s was also downloaded to a third MS.

The simulations adopted the mandatory settings for a 10.67 Mbps downlink (DL) rate with 3:1 DL/UL sub-frame ratio with WiMAX frame size of 5 ms, 16-QAM ½ modulation over a 10 MHz channel with IEEE 802.16e recommended antenna heights and transmit/receive powers. The channel model was deliberately kept simple for comparison purposes, with a Uniform distribution, BL_{mean} = 0.008. This model can still potentially result (if not corrected) in packet losses of up to 10%.

III. EVALUATION

Table 1 is the result of adaptive Raptor channel coding of the two video streams at two different streaming rates. The packet drop rates represent those packets that were corrupted by channel noise but could not be repaired. 'Corrupted packets' represent those packets that were affected by channel noise but that were repaired. This has resulted in no more than 20 ms delay before a packet is declared successfully received, compared to no more that 10 ms for uncorrupted packets, both delays being acceptable over normal path lengths. The objective video quality in all cases was good (over 30 dB), with the higher motion video clip benefitting most from the adaptive FEC scheme.

The effect of withdrawing repair packets is demonstrated in Table 2 as a representation of multicast delivery. The main implication is a decrease in video quality. This is most likely to impact on clips with higher motion. We judge objective video quality less than 25 dB as poor. Thus, again content type is critical.

We subsequently used Raptor coding at a fixed rate and raised the rate until all clips were received at greater than 30 dB PSNR. As recorded in Table 3, to achieve this in the given channel conditions implies a redundant data rate of 13.5%. In comparison, Table 4 gives the mean overhead from the adaptive scheme resulting in the performance of Tables 1 and 2. Notice that content type remains important: the overhead is higher when streaming the more complex *Football*. In respect to multicast delivery, the adaptive scheme cannot completely anticipate the impact of the channel but a fixed rate overhead of 13.5% is high. Therefore, the desirable redundant rate probably lies between the purely adaptive rate and the given fixed rate.

IV. CONCLUSION

Commercial IPTV may provide a baseline multicast service together with a value-added unicast service. In order to maintain cell capacity, it is not sensible to throw-away bandwidth with excessive FEC protection. Therefore, this paper advocates a flexible scheme that turns off repair packets when in multicast mode but includes a fixed-level of FEC provision in addition to the adaptive provision, according to desired multicast video quality. Validation in a real environment is the next step.

Table 1. Unicast CBR streaming with adaptive Raptor coding and repair packets

CBR datarate:	*Football* 500 kbps	*Football* 1 Mbps	*Paris* 500 kbps	*Paris* 1 Mbps
Packet drops (%)	0.6	0.88	1.28	1.66
Packet delay (s)	0.0068	0.0083	0.0067	0.0084
Mean PSNR (dB)	31.21	36.26	33.16	35.48
CPs (%)	2.94	8.07	4.11	8.55
CPs delay (s)	0.0163	0.0188	0.0163	0.0175

Notes: CPs = Corrupted packets, mean packet end-to-end delay is shown, 2% intra-refresh MBs, CIP, IPPP… frame structure.

Table 2. Multicast CBR streaming with adaptive Raptor coding without repair packets

CBR datarate:	*Football* 500 kps	*Football* 1 Mbps	*Paris* 500 kbps	*Paris* 1 Mbps
Packet drops (%)	5.11	7.55	5.25	11.28
Packet delay (s)	0.0068	0.0083	0.0068	0.0084
PSNR (dB)	21.97	25.61	29.26	28.69
CPs (%)	0	0	0	0
CP delay (s)	0	0	0	0

Notes: CPs = Corrupted packets, mean packet end-to-end delay is shown, 2% intra-refresh MBs, CIP, IPPP… frame structure.

Table 3. Multicast CBR streaming with Raptor coding at fixed-rate (13.5%) without repair packets

CBR datarate:	*Football* 500 kbps	*Football* 1 Mbps	*Paris* 500 kbps	*Paris* 1 Mbps
Packet drops (%)	0.25	2.30	1.55	2
Packet delay (s)	0.00698	0.00877	0.06921	0.00915
Mean PSNR (dB)	31.77	30.49	33.39	32.97
CPs (%)	0	0	0	0
CPs delay (s)	0	0	0	0

Notes: CPs = Corrupted packets, mean packet end-to-end delay is shown, 2% intra-refresh MBs, CIP, IPPP… frame structure.

Table 4. Mean overhead from adaptive channel coding for multicast CBR streaming

Video trace/CBR datarate:	Average datarate overhead % for multicast, adaptive Raptor code
Football 500 kbps	8.05
Football 1 Mbps	8.79
Paris 500 kbps	7.53
Paris 1 Mbps	7.78

REFERENCES

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