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Engineering wireless broadband access to IPTV

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ABSTRACT

IPTV is now extending to wireless broadband access. If broadband video streaming is to achieve competitive quality the video stream itself must be carefully engineered to cope with challenging wireless channel conditions. This paper presents a scheme for doing this for H.264/AVC codec streaming across a WiMAX link. Packetization is an effective tool to govern error rates and, in the paper, source-coded data-partitioning serves to allocate smaller packets to more important data. A packetization strategy is insufficient in itself, as temporal error propagation should also be addressed by insertion of intra-coded data. It may be necessary to include redundant packets when channel conditions worsen. The whole should be protected by application-layer rateless coding. Therefore, the contribution of the paper is a complete scheme comprised of various protection measures aimed at robust IPTV streaming. Due to computational overheads, the scheme is aimed at the new generation of smartphones with GHz CPUs.

1. Introduction

Due to the flexibility of network delivery, Internet Protocol TeleVision (IPTV) is attractive as an alternative to digital TV over terrestrial channels, though it may suffer from: delays due to congestion; and packet losses leading to fluctuations in video quality. It does represent an intrusion into personal privacy, as individual viewing habits can be tracked, although advertisers may benefit from this facility. Whereas terrestrial TV is limited to a fixed channel broadcast schedule, i.e. linear TV, in contrast IPTV can offer pause-TV (when a partially-viewed program is cached for later viewing), catch-up TV [1] and time-shifted TV (when a program is re-aired in a different time zone), as well as varieties of Video-on-Demand (VoD). It also opens up the possibility of interactive TV and hybrid TV (a combination of terrestrial broadcasting with network delivery).

A crucial aspect of engineering IPTV is configuring the video codec in order to achieve good performance over a wireless link for flexible access. In this paper, we demonstrate effective codec configuration for wireless IPTV video streaming. In this way, the paper also provides a reference for content providers to pre-encode their video using a suitable codec configuration for broadband wireless networks, especially WiMAX. The paper also shows that multiple protection measures, as detailed in the paper, are necessary as a complete protection scheme for such an IPTV service and we show how our scheme achieves robust delivery of video. As bursty error conditions present a major problem to compressed video stream, the research reports performance over broadband wireless access links experiencing this type of error pattern. That problem arises [2] because isolated errors are less harmful than the same number of errors appearing as a contiguous burst, as video compression relies on prediction from prior data. The paper will be of interest to those charged with deploying a broadband wireless IPTV service, as it contains an assessment of the current prospects for wireless IPTV.

In this paper, H.264/Advanced Video Codec (AVC) [3] standard codecs are assumed, as though the High Efficiency Video Codec (HEVC) was standardised at the beginning of 2013, experience shows that it will take many years to be deployed, if indeed it is extensively used for streaming over wireless, given the absence of error resilience and concealment features [4]. The absence of error protection features may arise either because HEVC is intended to be used with Dynamic Adaptive Streaming over HTTP (DASH), a multi-streaming system for reliable TCP [5] or because HEVC's considerable coding gain is achieved by abandoning Macroblocks (MBs) for tree-structured Coding Units. HEVC is suitable for 720p High Definition (HD) network delivery, where the up to 50% lower bitrates over H.264/AVC compensate for the high frame rates, at least 50 frame/s at that resolution. Indeed, HEVC delivery chains have made quicker progress [6] than expected, though evaluation has shown that, without persistent HTTP connections, streaming is subject to delays and interruptions when using DASH [7].

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The underlying transport protocol for HTTP is TCP, which retransmits packets when acknowledgments fail. This implies that there is no need for the channel coding used in our paper. However, over a wireless channel, TCP has difficulty distinguishing between packet loss due to congestion and packet loss due to transmission errors, implying that packets will be retransmitted even if they may be again lost through a persistently poor wireless channel. DASH compensates for TCP's behavior by allowing the client to control the bit-rate of the stream being downloaded (by selection between a set of streams with differing bit-rates). Unfortunately, during periods of heavy network congestion, DASH defaults to predominantly TCP control rather than client control. Study of a Netflix application [8] showed service interruptions of around 300 s, which is larger than a typical Windows wired device buffer of 240 s. The risk to display interruption on an Android device is still greater, as the typical buffer size is only 30 s. From the evidence of the performance studies referred to in [8], the performance of DASH has until recently been relatively poorly understood. The main reason [9] that commercial companies have implemented such multi-stream systems is not delivered video quality, which is difficult to monitor in a DASH-based system, but the compatibility of DASH with off-the-shelf web servers and existing content-delivery networks. The simpler UDP transport system, which is the subject of this paper: reduces the risk of video service interruption; does not rely on network over-provisioning [9]; and as a result potentially represents a greener solution.

The authors' robust scheme for streaming video over wireless broadband access has been simulated for IEEE 802.16 (WiMAX) systems [10]. WiMAX may have recently lost the technological competition with Long Term Evolution (LTE) [11] in developed Western countries but it is still being deployed in rural areas [12] and in countries where 3G cellular phone coverage is poor, including Africa and the Middle East. WiMAX is also attractive [13] for backhauling from local IEEE 802.11 networks. Though the authors' scheme as a whole has been analysed in previous works such as in [14,15], the individual codec settings have not been analysed in isolation. In fact, it has been suggested to the first author that a very helpful service to the system developer community would be to analyze codec settings independently of each other, which is what this paper sets out to do.

The authors' scheme combines data-partitioning as a form of error resilience [16] with the addition of Forward Error Correction (FEC) using rateless channel coding [17] at the application layer, together with retransmission of extra redundant data when required. Retransmission is limited to one round to avoid accumulating latencies. The current authors have introduced into their video streaming scheme various error resilience measures [18] that exist in the literature: different rates and types of Intra-Refresh (IR) Macroblocks (MBs) [19], Constrained Intra Prediction (CIP) [20] and where necessary, redundant data-partitioned Network Abstraction Layer (NAL) units (codec level packets) [21]. The impact of each of these measures is analyzed in isolation from each other, for Constant Bit Rate (CBR) as well as Variable Bit Rate (VBR) streaming. CBR allows storage and bandwidth capacity to be planned in advance, at a cost in video quality fluctuations. VBR enables greater compression efficiency relative to CBR, which is why it is generally used for disc storage. VBR can benefit from two or even three-pass encoders, which are unsuitable for live video compression. The relative merits of CBR and VBR are further discussed in [22]. In general, we have noticed that many researchers on similar topics have not explored the effect of video settings on their schemes and the authors believe that it is important to investigate this aspect of any protection scheme in order to understand the overall outcome of the scheme. In particular, it is important to determine how critical the video codec settings are to the success of a protection scheme. Is the scheme robust to changes or should certain settings be set within a given range?

The remainder of this paper is organized as follows. The following Section adds further information on how IPTV can be delivered to the consumer, as well as supplying background technical context. Section 3 selects research from the literature that reveals the motivation behind the codec-based approach to video streaming used in this paper. Particular attention is paid to video streaming over WiMAX in that section. Section 4 then outlines the approach taken to protect IPTV streams. As the main focus of this paper is the configuration of the scheme rather than the scheme itself, the description is necessarily brief. Section 5 continues by detailing how the video codec settings were modelled in order to provide the evaluation that appears in Section 6. Section 7 summarizes the findings and rounds off with some observations about video streaming in this environment.

2. Context

Readers requiring further information on: IPTV, technical context of H.264/AVC data-partitioning, and/or Raptor codes can consult this Section.

2.1. IPTV delivery

There are two basic forms of IPTV: (1) That delivered over closed or proprietary managed networks, including cable TV, often to set-top boxes (STBs) that perform decoding and possibly decryption; and (2) That delivered over the unmanaged public Internet, often displayed directly on desktop or laptop computer screens. The latter may be called Web or Internet TV [23] or latterly Over-the-Top (OTT) TV, as a way of distinguishing it from the service that the telecommunications companies hoped to challenge terrestrial broadcasters with by means of a high-quality service delivered over closed networks. Increasingly the industry trend, apart from cable TV, is towards the latter model of IPTV, i.e. OTT TV. There is no place for STBs when mobile IPTV [24] is delivered, hence, our interest in OTT TV. The two forms of IPTV may differ in: the picture quality of the stream offered (lower for unmanaged); the amount of content available (higher for unmanaged); the formats that the video is compressed to (the need to update the STB is an issue); the way content is secured (unmanaged delivery may not be encrypted or employ selective encryption [25] instead); and the frame resolutions presented (lower resolutions for unmanaged delivery). A flexible way to deliver IPTV is to set-up (and tear-down) connections [26] using the Real-Time Streaming Protocol (RTSP) (over reliable TCP transport), with subsequent data delivery using the Real-time Transport Protocol (RTP) over UDP transport. The Real-time Control Protocol (RTCP) can also allow end-to-end feedback to the IPTV server to control the bit rate. RTSP also can support so-called trick mode functionality such as rewind and pause.

To allow unmanaged delivery, OTT TV, to compete with Standard TV (SDTV) Quality-of-Experience (QoE), TV and video material can be locally cached [27], reducing latency to the access link, which in our paper is represented by a WiMAX base to subscriber station link. Whether streaming over managed or unmanaged networks, packets will be lost at the access network. This is the case, whether over broadband wireless or xDSL (Digital Subscriber Line), as the latter also suffers from burst errors [28]. Prior to that, whether managed or unmanaged networks are in use, video streams are aggregated over high-capacity optical networks, such as in Swisscom's Bluewin IPTV service [29]. Only Passive Optical Networks (PONs) can reduce the error rates at the access link but