Evaluating the Impact of Different Packing Schemes on MPEG-2 Transport Stream Quality over Error Prone Wireless ATM Links

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1. INTRODUCTION

Recently, Wireless ATM demonstrators like the WAND system [5] have gained significant attention due to their promising technology. The combination of mobility with broadband networking will enable a new class of applications: wireless broadband applications. As an example one could think of mobile TV-sets where a high performance laptop retrieves high quality MPEG-2 Transport Streams from a VoD server over wireless ATM using a certain set of QoS parameters. However, radio channel impairment will lead to significant cell loss at distances of 20 meters (AP-MT) and it is of major importance to evaluate the impact of cell loss caused by a typical wireless ATM system on video quality. These results can then be used to decide what kind of algorithms and characteristica a wireless data link layer (WDLC) below the ATM layer should provide in order to guarantee a good video quality. Additionally, the set of optimal types of packing schemes used to encapsulate the MPEG-2 TS packets into AAL5 PDUs can be determined.

MPEG-2 is the emerging industry standard for high quality video and audio compression applicable both to Video on Demand (VoD) scenarios and high quality real-time conferences based on specialized hardware. MPEG-2 Transport Streams are defined for multiplexing different elementary stream types (audio, video or private) to form a program. Transport streams consist of multiplexed streams which do not have a common time base. They are made of fixed length (188 bytes) packets which simplifies efficient error detection and recovery techniques.

2. MPEG-2 TRANSPORT STREAM SIMULATION FOR WIRELESS ATM

The MPEG-2 TS was designed for transporting MPEG-2 over noisy environment. Synchronization and continuity is assured by inserting timestamps (PCRs, Program Clock References), which also facilitates clock recovery at the decoder. The header (4 byte) of a MPEG-2 TS packet starts with an unique sync-byte (0x47). The transport error indicator (TEI) can be used to notify the decoder about possible errors so that error concealment techniques can be employed. The payload contains the actual audio, video or data for the MPEG-2 decoder to be used.

A suitable AAL has to be chosen when transmitting the TS packets over ATM links. The most studied AAL for this purpose is AAL5, which supports variable length PDUs. Additionally, VBR traffic is supported making it suitable for VBR MPEG-2 TS of the future. However, there are no means for removing jitter in AAL5 because no timing information is included. Furthermore, if an AAL5 PDU is lost or corrupted, there is no way to recover it in contrast to AAL1 with FEC possibility. AAL5 can detect errors due to a CRC field but an erroneous AAL5 PDU is discarded. So, if more than one MPEG-2 TS are encapsulated in a single AAL5 PDU and the AAL5 PDU is corrupted or lost, all MPEG-2 TS packet contained in the AAL5 PDU are lost, which might have severe impact on the visual quality of the decoded video or audio data.

Different ways for packing and aligning the TS packets inside the AAL5 PDU exist (i.e. to use padding between the single TS packets or to use padding at the end of the last TS packet in case the last ATM cell is not filled). For example, if each TS packet is encapsulated in a distinct AAL5 PDU, then five ATM cells are needed at the ATM layer and the last cell is only partially filled. From the point of efficiency, encapsulating $2+12k$, $k=0,...$ TS packets in a single AAL5 PDU results in the last cell of the PDU being filled up, all other combinations result in partially filled last cells. Here, we analyze the suitability of the so called *n*TP-Tight schemes [3], where all *n* MPEG-2 TS packets are packed into one AAL5 PDU directly. The efficiency of the packing scheme calculates to

$$N_{nTP-Tight} = \frac{Sys \times n}{\left\lceil \frac{n \times 188 + 8}{48} \right\rceil \times 53}$$

at MPEG-2 system level (Sys = 184) or at AAL 5 level (Sys = 188) and includes 4 Byte TS header, 8 Byte AAL5 trailer and 5 Byte ATM cell header. The additional buffer for holding the AAL5 payload calculates to $n \times 188 + 8$ bytes. The additional packing delay depends on the number of MPEG-2 TS packets encapsulated and on the transport rate. The more TS packets are carried inside a single AAL5 PDU, the more efficient the packing scheme is, but the more packing delay is introduced and the more TS packets a bit error affects.

For evaluating the impact on visual quality we used the simulation setup depicted in Figure 1. Different sources of influence are combined to form a model for the physical layer of the WAND system: fluctuations, different transceiver characteristics, indoor environment and the impact of channel dispersion are combined to form a Stochastic Radio Channel Model (SRCM). The parameters model a mobile terminal moving around an access point at fixed distance with a velocity of 1 m/s. The carrier frequency for the WAND system was 5.2 GHz. The mean number of paths was set to 8 with a random distribution. The standard deviation of the path energy was 2.0 allowing to model the shadowing effects. A delay spread of 50 ns was adopted for simulating a typical indoor environment. More information on the channel model can be found at [1].

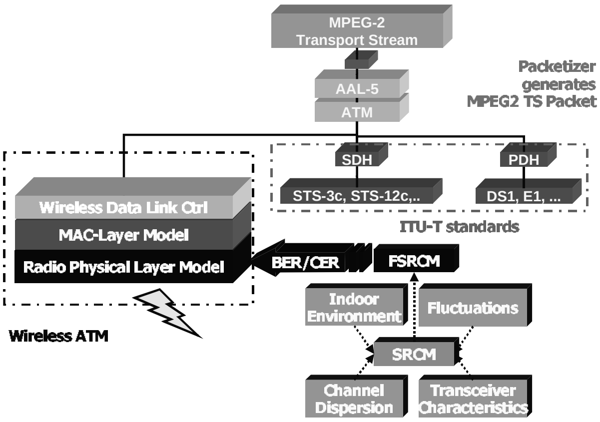

Figure 1. Simulation Setup for Wireless ATM

In [4], the signal power of the continuous state model was discretized in order to generate a Finite State Radio Channel Model (FSRCM). Here, a semi-Markov process was used to describe the time-variant behavior of the SNR at the receiver side. The FSRCM gives for each state the corresponding SNR. By applying the OFDM (Orthogonal Frequency Division Multiplexing) coding scheme for the WAND radio modem, a relationship between the SNR and the BER or the CER can be obtained. Then, a model of the WAND MAC protocol is applied to get the AAL5 PDU loss rate at any given point of time. We base our simulations directly on the BER/CER calculated from this model. We can then interpret the results of the simulations given a channel, which does not tolerate any additional delay, so all the cells send from a MT to an AP are not re-transmitted at the WDLC in case of bit-errors at the PHY-layer. Similarly, no forward error correction (FEC) is applied (empty WDLC).

We have run simulations based on three different radio conditions: the three set-ups showed a mean radio SNR of (30;38;44) dB corresponding to a distance of (32;21;15) m between the mobile terminal and the access point and a mean CER of ($9.85x10^{-2}$; $9.5x10^{-3}$; $8x10^{-4}$). Momentarily high CER values of (0.89; 0.44; 0.041) may persist over longer period of time due to shadowing effects. The transmission of a MPEG-2 TS was simulated based on the test sequence susie_015 at 1.5 mbps The MPEG-2 TS contains only the compressed video data in the format 352x288 at 25 fps. Additionally, we used a 8 mbps test sequence showing similar results.

3. SIMULATION RESULTS

The radio model calculated for each state a CER and the test program dropped the whole AAL5 PDU (and therefore all *n* TS packets encapsulated) in case of transmission errors. The typical behavior of AAL5 is to drop a whole AAL5 PDU in case of a CRC error. The receiver then forwarded the correctly received PDUs to the de-multiplexer and decoder.

The quality of the 44 dB sequence was judged to be very good, whereas the 38 dB sequence was acceptable. Errors over longer period of time were visible for the 30 dB simulation. Figure 2 shows frame 84 for the 30 dB (right) and 38 dB (left) run. Clearly, the better radio channel showed better performance The errors are localized to macroblock level due to the MPEG-2 video coding behavior. The same frame for the 44 dB run was almost perfect. During our runs we found all kind of errors especially in the 30 dB case: motion jerkiness, frame freezing, color cycling, error blocks and tiling or pixelation. In case the AAL5 PDU contained TS packets which includeed a frame header at Elementary Stream level, the whole frame was lost by the decoder and error concealment techniques would be necessary to improve the video quality.

Figure 2. Frame 84 for the 2 TS scheme (30 db, 38 dB)

From the PSNR curves [2] it can be seen that the image quality decreases as the radio channel quality decreases. The PSNR curves are based on the luminance channel and show that in general the 1-TS scheme is the best. However, no significant difference is noticeable when viewing, because the scenes are played at 25 fps. In some situations, the 2 TS scheme shows better visual quality than the 1 TS scheme, whereas in other situations the 8 TS scheme is better than the 2 and 1 TS scheme depending on the wireless channel characteristics. The more TS packets are encapsulated and no errors occur the better the quality. But if errors occur more frequently, encapsulating less TS packets gives better results. As a consequence, a wireless ATM system could also operate more efficiently and use the 8 TP scheme without sacrifying the quality too much, if the radio quality is good enough. Our simulations showed, that at least 38 dB signal strength are necessary for acceptable video quality, which corresponds to a distance of 21 meters (MT-AP).

4. REFERENCES

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