Optimal Channel Changing Delay for Mobile TV over DVB-H

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Abstract— **This paper provides an analysis on the optimal channel changing delay in DVB-H (Digital Video Broadcasting for Handhelds) channels for Mobile Television. DVB-H uses a time-sliced transmission scheme to reduce the power consumption used for radio reception in DVB-H receivers. Channel changing delay, i.e. changing from one audio-visual service to another, is increased due to the time slicing scheme in DVB-H. One of the significant factors in channel changing delay is the Decoder Refresh Delay. The Decoder Refresh Delay is the time from the start of video decoding to the start of correct output from decoder. This delay is minimized when a time-slice starts with a random access point picture such as an instantaneous decoding refresh (IDR) picture in H.264/AVC standard. In DVB-H, encapsulation into time-slices is performed independently from content encoding. At the time of encoding, the exact time-slice boundaries are typically unknown, and therefore it is impossible to align the location of IDR pictures to time-slice boundaries. The average decoder refresh delay can decrease by frequent IDR pictures in the bit stream. However, using very frequent IDR pictures drops the compression efficiency and the quality of compressed video dramatically. Another factor in channel changing delay is the delay required to compensate the variation in bit rate. In video streaming over DVB-H the improved quality and compression efficiency obtained by using variable bit rate should be exploited. Higher quality and compression performance can be provided by higher delay. Moreover, when changing channels, a delay is required until the start of the desired time-slice and a further delay is incurred to complete the reception of the entire time-slice. These delays depend on the time-slicing parameters that define the power saving percentage obtained as the result of the time-slice scheme. The lower the receiver power consumption, the higher delay is required. Therefore, there is a strong multilateral relationship between the quality of compressed video, the channel changing delay and the power consumption in the receiver. Simulations were conducted and based on the simulation results an optimal operating area is proposed.**

Index Terms— **Channel changing, channel switching, delay, Digital Video Broadcasting-Handheld (DVB-H), Mobile TV, video coding.**

I. INTRODUCTION

DIGITAL Video Broadcasting for Handheld terminals (DVB-H) is an ETSI specification for delivering broadcast services to battery-powered handheld receivers [1], [2]. DVB-H is mainly based on the DVB-T specification for digital terrestrial television. However, it adds a number of features designed to consider the limited battery life of handheld devices and the particular environments in which such receivers operate. Services used in mobile handheld terminals require relatively low bit rates. The estimated maximum bit rate for streaming video using advanced compression technology like MPEG-4 is in the order of a few hundred kilobits per second. A DVB transmission system usually provides a bit rate of 10 Mbps or more. This provides a possibility to significantly reduce the average power consumption of a DVB-H receiver by introducing a scheme based on time division multiplexing. This scheme is called Time-slicing. Time-slicing also supports a quasi-optimum seamless handover by accomplishing the changing of the reception from one transport stream to another during the off-time. To reduce the power consumption in handheld terminals, the service data is time-sliced and then sent into the channel as bursts at a significantly higher bit rate compared to the bitrate of the audio-visual service. Time-slicing enables a receiver to stay active only a small fraction of the time, while receiving bursts of a requested service. It significantly reduces the power consumption used for radio reception. DVB-H also employs additional forward error correction to further improve mobile and indoor reception performance of DVB-T.

Channel changing delay in DVB-H refers to the time between the start of switching and the start of the media rendering for newly-joined channel. The channel changing delay consists of several parts including: delay until the start of the desired time-slice or burst, reception duration of a complete burst, delay to compensate the size variation of bursts, delay to compensate the variation in bitrate, delay to compensate the synchronization between the associated streams (e.g. audio and video) of the streaming session and delay until a media decoder is refreshed by a random access point to produce correct output samples.

The use of time-slicing in DVB-H has enlarged the channel changing delay. One of the significant factors in channel changing delay is Decoder Refresh Delay or the time from the start of video decoding to the start of correct output from decoder, which is minimized when a time-slice starts with a random access point picture such as an instantaneous decoding refresh (IDR) picture in H.264/AVC video coding standard. In DVB-H, encapsulation to time-slices is performed in a network element called IP encapsulator independently from content encoding. At the time of encoding, time-slice boundaries are typically not known exactly, and it is therefore impossible to align the location of IDR pictures relative to time-slice

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boundaries. It should be noted that if the decoder started decoding from an IDR picture that is not at the beginning of a time-slice immediately when the time-slice is received, the input buffer of the decoder would be completely drained before the arrival of the next time-slice and there would be a gap in video playback corresponding to the play out duration from the beginning of the time-slice to the first IDR picture. Typical intervals between time-slices containing content for a particular audio-visual service may range from one second to a couple of seconds. If IDR pictures are placed randomly in a normal bit stream and the average IDR picture interval is equal to the time-slice interval, the expected decoder refresh delay is approximately half of the time-slice interval. The average decoder refresh delay can be decreased by using more frequent IDR pictures in the bit stream. However, since an IDR picture can consume a bit budget from 5 to 10 times more than an inter-prediction picture in variable bit rate mode, using frequent IDR pictures drops the compression efficiency and quality of compressed video remarkably. Another factor in channel changing delay is the delay required to compensate the variation in bit rate. For video streaming over DVB-H application the advantages of variable bit rate video can be exploited. For most video contents, a variable bit rate video can provide better visual quality and coding efficiency than a constant bit rate video [3]. A higher quality and compression performance can be obtained by more variations in bit rate. However, the increased variations in bit rate require a larger initial buffering delay. Moreover, when channel changing, a delay is required until the start of the desired time-slice or burst and another delay until the reception of time-slice is completed. The sum of these two delays namely receiving delay depend on the burst bitrate and burst size which define the percentage of power saving for the receiver. A lower power consumption for the receiver needs a higher receiving delay. The other factors in channel changing delay are not discussed here.

There are strong multilateral relationships between the channel changing delay, video quality and power consumption in DVB-H receiver. In this paper, we try to evaluate optimal values for the decoder refresh delay, buffering delay and receiving delay to achieve better quality for compressed video with minimum channel changing delay and power consumption in DVB-H receiver. Optimum values for buffering delay and decoder refresh delay are extracted empirically based on video quality. Moreover, optimum receiving delay is derived analytically based on the percentage of power saving for the receiver.

This paper is organized as follows: Section II of the paper presents the details of analytical method used for searching of optimal receiving delay. The optimal buffering delay and decoder refresh delay are studied in Section III. Simulation results are presented in Section IV. The paper is closed with conclusions in section V.

II. OPTIMUM RECEIVING DELAY

Receiving delay depends on the time slicing structure and the number of service in each time slice. In a special case, when channel changing is accomplished between services transmitted in the same time slice, the receiving delay can be close to zero. In this paper, the general case where channel changing is accomplished between two services in different time slices is studied. In the general case, the channel changing delay can have a very large value: typically in the order of seconds. Fig. 1 depicts the burst parameters in time-slicing scheme [4]. *Burst Size* (B_B) refers to the number of *Network Layer* bits within a burst. *Burst Bitrate* (R_B) is the bitrate used by a time-sliced elementary stream while transmitting a burst. *Constant Bitrate* (R_C) is the average bitrate required by the elementary stream when not time-sliced. *Burst Duration* (T_B) is the time from the beginning to the end of the burst. *Off-time* (T_{off}) is the time between bursts. The power saving percentage can be expressed as.

$$P_S = \frac{T_{off}}{T_{on} + T_{off}} \times 100, \tag{1}$$

where T_{on} denotes *On-Time* or the time duration when the radio receiver is on. An extra time namely *Synchronization Time* (T_S) is required by a receiver to re-acquire lock onto the signal before the start of the reception of the next burst. Therefore the on-time can be expressed as:

$$T_{on} = T_B + T_S, \tag{2}$$

The burst duration depends on the burst size and burst bit rate as:

$$T_B = \frac{B_B}{R_B(1-h)}, \tag{3}$$

where h compensates the overhead caused by the transport packet and section headers. The constant bit rate or the average bitrate of service data can be calculated as:

$$R_C = \frac{B_B}{T_{on} + T_{off}}, \tag{4}$$

Therefore, for a given burst bitrate and constant bitrate the percentage of power saving is derived as:

$$P_S = \left(1 - R_C\left(\frac{1}{R_B(1-h)} + \frac{T_S}{B_B}\right)\right) \times 100 \cdot \tag{5}$$

To find out the relationship between the power saving and channel changing delay, consider a simple case where neighboring channels have similar time slicing parameters. When channel changing, a delay is required until the start of the desired burst and another delay until the reception of burst

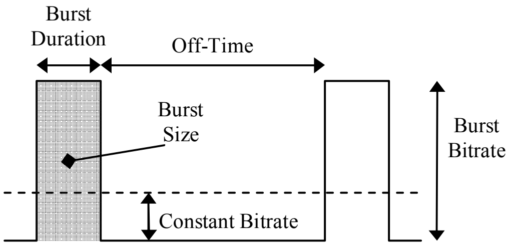

Fig. 1. Burst parameters

is completed. The sum of these two delays or receiving delay in average is expected to be:

$$D_R = \frac{1}{2}(T_{on} + T_{off}) + T_{on}, \tag{6}$$

$$D_R = T_S + B_B\left(\frac{1}{2R_C} + \frac{1}{(1-h)R_B}\right). \tag{7}$$

Combining (5) and (7) a closed form function between power saving and receiving delay is given as:

$$P_S = \left(1 - \frac{1}{D_R - Ts}\left(\frac{T_S}{2} + \frac{R_C D_R}{R_B(1-h)}\right)\right)\times 100 . \tag{8}$$

For transmission of an elementary stream with a desired average bit rate of R_C, by a transmission channel with the bit rate of R_B, different operating points on the power saving curves (P_S, D_R) can be found from (8). Considering a typical values for h (0.04 or 4%) and T_S (200 ms), a set of power saving curves are depicted in Fig. 2. The power saving curves are computed for two different values of R_B (5 Mb/s and 10 Mb/s) and three different values of R_C (300, 400, 500 Kb/s). The curves in the power saving graphs drop dramatically when the on-time, including the synchronization time and the burst duration, becomes comparable with the off-time. To show the impact of the synchronization time on power saving curves, for two different values of synchronization time (200 and 250 ms) the power saving curves are depicted in Fig. 3. The graphs show that the percentage of power saving is more sensitive to the synchronization time where the receiving delay has smaller values. The provided power saving curves are used to find an optimal operating area with a small receiving delay and a large power saving percentage for the receiver.

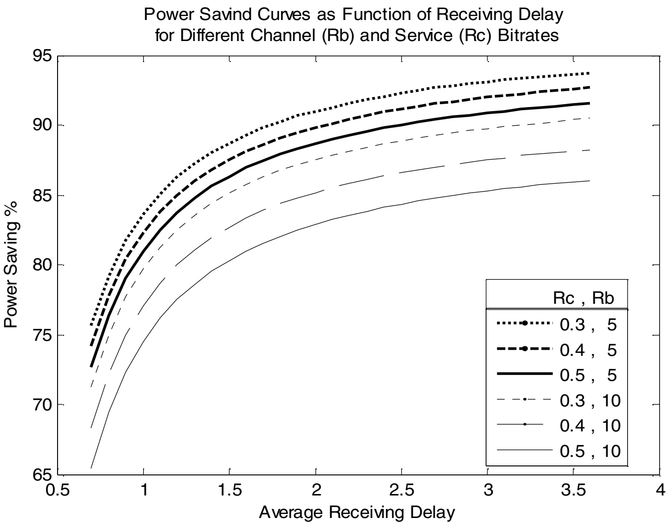

Fig. 2. Power saving as a function of Receiving Delay

III. OPTIMUM BUFFERING AND DECODER REFRESH DELAY

While at least one random access point in each time slice is desired, the maximum value of decoder refresh delay is defined by the power saving percentage. The average value of decoder refresh delay, which decreases by frequent IDR pictures in the bit stream, is constrained by the compression performance and video quality. For a given bitrate, if the number of frequent IDR picture increase, a part of allocated bit budget to the inter-prediction pictures is moved to the IDR pictures and consequently the average quality of encoded bit stream degrades.

The buffering delay is defined according to variation in bitrate. Although the buffering delay would be minimized if a constant bitrate is used for video bit stream, by allocating a small delay to buffering the advantage of variable bitrate can be used. A better average quality for compressed video is achieved at the expenses of more variation in bitrate and thereafter higher buffering delay.

The compression performance and quality of encoded video not only depends on the frequency of IDR pictures and variation in bitrate but also related to the used rate control algorithm.

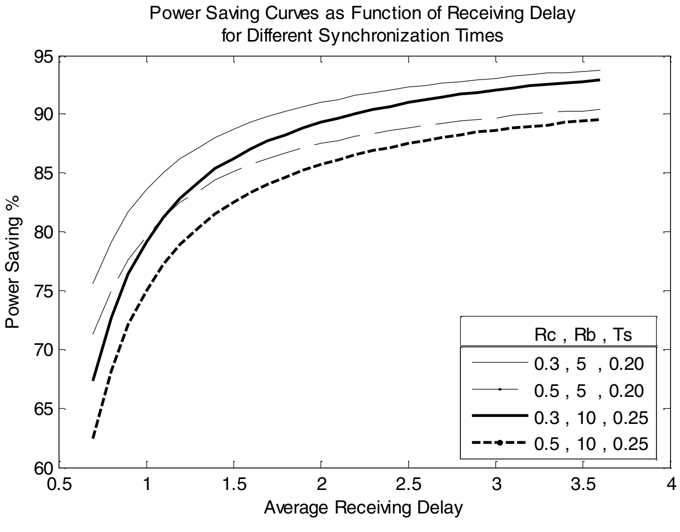

Fig. 3. Power saving as a function of Receiving Delay

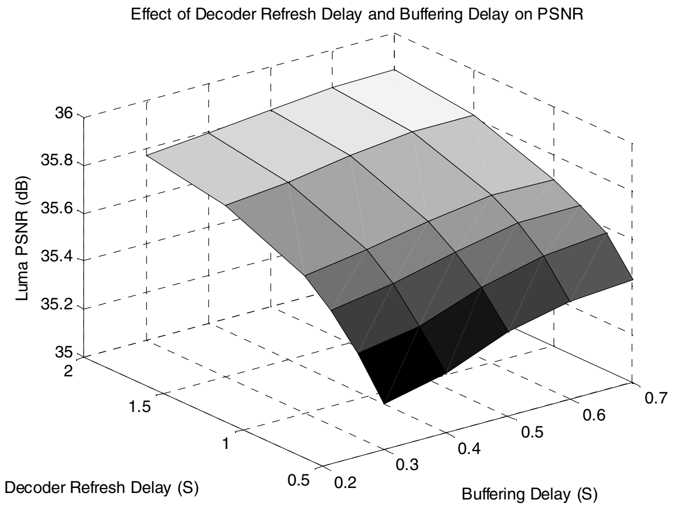

Fig. 4. Effect of decoder refresh delay and buffering delay on Luma PSNR

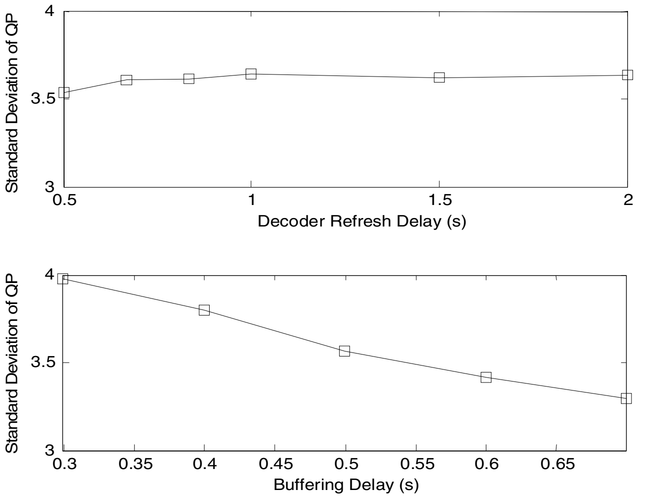

Fig. 5. Effect of decoder refresh delay and buffering delay on the standard deviation of quantization parameter

To find optimal values for decoder refresh delay and buffering delay an experimental method was used. A set of simulation were run and in each case the average quality of compressed video was measured for different buffering delays and decoder refresh delays. A fuzzy rate control algorithm similar to algorithm presented in [5] was used. The rate control algorithm was optimized such that it can provide a high average quality comparable with the quality of constant quality bit streams for all testing point in this simulation. To measure average values for the decoder refresh delay and buffering delay we provided 4 different long video sequences including news, sport, music and movie contents. The video sequences were encoded with different encoding parameters related to decoder refresh delay and buffering delay and for each case the PSNR of luma component, the mean and the standard deviation of quantization parameter of encoded frames were measured as quality criteria. Sample simulation results are depicted in Fig. 4 and Fig. 5 for a typical parameter set including: 300 kb/s video, 15 fps and QVGA picture format. Fig. 4 shows the average PSNR of compressed video on luma components as a function of two different delays: decoder refresh delay and initial buffering delay. Table I shows some numerical results related to the graph depicted in the Fig. 4. When the decoder refresh delay decreases to small values, it means the number of IDR pictures increases in the bit stream. Therefore, the bit budget is moved from the inter-prediction pictures to IDR pictures and consequently the average quality degrades. The degradation in PSNR is higher when the decoder refresh delay has smaller values because the movement of bit budget is higher in these cases. Furthermore, Fig. 4 shows the effect of buffering delay on the PSNR of encoded bit streams. To achieve a low buffering delay, the rate controller decreases the bit budget allocated to the IDR pictures that decrease the quality of IDR pictures and thereafter the quality of consequent inter-prediction pictures. This degrades the average quality of compressed video. The degradation in PSNR is more critical when the number of IDR pictures increases or when the decoder refresh delay decreases. Two graphs in Fig. 5 show the average (over all bit streams) of standard deviation (over all pictures in each bit stream) of quantization parameter as functions of the decoder refresh delay and the initial buffering delay. As shown the standard deviation of quantization parameter is an almost constant function of decoder refresh delay and it means that the performance of the used rate control is independent of picture type in the bit stream. In other words, the rate controller has a constant performance on all operating points and hence all the provided results can be interpreted independently of the rate controller. Fig. 5 shows that the standard deviation of quantization parameter is a decreasing function of buffering delay and it means that a more constant quality of encoded video needs a higher buffering delay.

TABLE I

EFFECT OF BUFFERING DELAY AND DECODER REFRESH DELAY ON AVERAGE PSNR. THE CONTENT OF TABLE SHOEW THE AVERAGE PSNR OF LUMA COMPONENT ON 4 VIDEO SEQUENCES WITH 900 FRAMES (EACH), 15 F/S, 300 KB/S AND QVGA PICTURE FORMAT

Decoder Refresh Delay (s)	**Buffering Delay (s)**				
	0.25	**0.30**	**0.40**	**0.55**	**0.75**
0.50	35.19	35.25	35.35	35.41	35.43
0.67	35.35	35.39	35.48	35.55	35.57
0.83	35.48	35.52	35.59	35.63	35.64
1.0	35.57	35.61	35.66	35.70	35.69
1.5	35.72	35.74	35.78	35.82	35.81
2.0	35.77	35.80	35.82	35.84	35.85

To obtain reliable results a large number of video pictures (about 360000 frames) from different contents with different encoding parameters were encoded during simulation. More details about the results are presented in the sequel.

IV. RESULTS OF STUDY

Results of study show that the average quality and the percentage of power saving are nonlinear increasing functions of delay that saturates to a limit for higher values of delay. While the minimum channel changing delay is desired, for each function the optimal operation point can be selected in an area where the saturation starts.

The powers saving curves for the burst bit rates of 5 and 10 Mb/s and average bitrates of 300, 400 and 500 kb/s are depicted in the Fig. 2. The graphs show that the percentage of power saving drops dramatically where the receiving delay is smaller than 1 seconds and it has gradual enhancement where the receiving delay is larger than 2 seconds. Moreover, power saving curves for different synchronization times in Figure 3 show that the sensitivity to synchronization time increase where the receiving delay become less than 1 second. According to these results a receiving delay of about 1 to 2 seconds is recommended.

From the visual quality point of view we believe that the PSNR criterion is not enough so we measured the variance of quantization parameter which corresponds to the variation in quality. Less variation in quality means higher visual quality. Simulation results show that the average quality of compressed video has a sharp drop where the decoder refresh delay is less than 0.7 second and where the buffering delay is less than 0.4 second. On the other hand, the average quality has a gradual enhancement where the decoder refresh delay is larger than 1.5 seconds and where the buffering delay is higher than 0.6 second. While a minimum channel changing delay with and maximum video quality is desired, it is recommended to select the operating point in an area between 0.5 to 1.0 seconds for the decoder refresh delay and 0.4 to 0.6 seconds for the buffering delay.

Results of more investigation show that the general properties of video bit stream such as bitrate, frame rate, and picture size may have a considerable impact on the optimal values of buffering delay and decoder refresh delay. Therefore, it is recommended to repeat the proposed optimization method when planning DVB-H services.

V. CONCLUSIONS

The optimal channel changing delay in Mobile TV over DVB-H (Digital Video Broadcasting for Handheld terminals) application was studied. Three factors in channel changing delay: the receiving delay, the buffering delay and the decoder refresh delay were investigated. An operating area based on simulation results that optimizes the percentage of power saving, video quality and channel changing delay in DVB-H receiver, was recommended.

REFERENCES

[1] ETSI, “Digital Video Broadcasting (DVB): Transmission systems for handheld terminals,” ETSI standard, EN 302 304 V1.1.1, 2004.

[2] G. Faria, J. A. Henriksson, E. Stare, P. Talmola, “DVB-H: Digital Broadcast Services to Handheld Devices,” *Proceeding of The IEEE*, V. 94, No. 1, Jan. 2006.

[3] T. V. Lakshman, A. Ortega, and A. R. Reibman, “VBR video: tradeoffs and potentials,” *Proc. IEEE*, Vol. 86, No. 5, pp. 952–973, May 1998.

[4] ETSI, “DVB-H Implementation Guidelines” *ETSI standard*, TR 102 377 V1.2.1, 2005.

[5] M. Rezaei, M. M. Hannuksela, M. Gabbouj, " Low-Complexity Fuzzy Video Rate Controller for Streaming," *IEEE Int. Con. on Acoustic, Speech and Signal Processing (ICASSP)*, Toulouse, France, May 2006.