TURBO-CODED TERRESTRIAL MOBILE VIDEO BROADCASTING

C.S. Lee, T. Keller, L. Hanzo

Dept. of Electr. and Comp. Sc., Univ. of Southampton, SO17 1BJ, UK.
Tel: +44-703-593 125, Fax: +44-703-593 045
Email: lh@ecs.soton.ac.uk
http://www-mobile.ecs.soton.ac.uk

ABSTRACT

In this contribution we investigated the performance of turbo-coded MPEG-2 compression based terrestrial mobile video broadcasting. Our experiments suggested that non-hierarchical, ie single-class protection of the MPEG-2 video stream exhibited a similar error resilience to twin-class data partitioning, since a high proportion of relatively sensitive video bits had to be relegated to the lower integrity subchannel, when invoking a powerful low-rate channel codec in the high-integrity protection class for the sake of ensuring the error-free reception of the more sensitive MPEG-2 video bits, such as control headers, etc.

1. BACKGROUND AND MOTIVATION

In recent years three DVB standards have emerged in Europe for terrestrial [1], cable-based [2] and satellite-oriented [3] delivery of DVB signals. The more hostile propagation environment of the terrestrial system requires concatenated Reed-Solomon [4, 5] (RS) and rate compatible punctured convolutional coding [4, 5] (RCPCC) combined with Orthogonal Frequency Division Multiplexing (OFDM) based modulation [6]. By contrast, the more benign cable and satellite based media facilitates the employment of blind-equalised multi-level modems using upto 256 quadrature amplitude modulation (QAM) levels [6]. These schemes are capable of delivering high-definition video at bitrates of upto 20 Mbits/s in stationary broadcast-mode distributive wireless scenarios.

The motivation of this contribution is to investigate the performance improvements attainable upon invoking powerful turbo coding instead of the standard convolutional coding and to assess the system's performance in mobile, rather than stationary propagation scenarios. Lastly, the potential of invoking twin-class error protection is appraised. Our results showed that with the advent of turbo coding for example 16QAM can replace 4QAM without dramatic complexity and power increases, while allowing us to double the video bitrate and hence improve the video quality.

The financial support of the following organisations is gratefully acknowledged: EPSRC, UK in the framework of the contract GR/K 74043; the European Commission;

ICT'2000, 22-25 May, Acapulco, Mexico

Area: Video coding and distribution

2. DVB TERRESTRIAL SCHEME

The block diagram of the DVB terrestrial (DVB-T) transmitter [1] is shown in Figure 1, which is constituted by an MPEG-2 video encoder, channel coding modules and an Orthogonal Frequency Division Multiplex (OFDM) modem [6, 7]. Due to the poor error resilience of the MPEG-2 video codec, strong concatenated channel coding is employed, consisting of a shortened Reed-Solomon RS(204,188) outer code [4], which corrects up to eight erroneous bytes in a block of 204 bytes, and a half-rate inner convolutional encoder with a constraint length of 7 [4, 5]. The overall code rate can be adapted by the variable puncturer, which supports code rates of 1/2 (no puncturing) as well as 2/3, 3/4, 5/6, and 7/8. The parameters of the convolutional encoder are summarised in Table 1. If only one of the two branches of the transmitter in Figure 1 is utilised, the DVB-T modem is said to be operating in its non-hierarchical mode. In this mode, the modem can have a choice of QPSK, 16-QAM or 64-QAM modulation constellations.

Rate	1/2
Constraint Length	7
k	1
n	2
Polynomials (octal)	171,133

Table 1: Parameters of the CC(n,k,K) convolutional inner encoder in the DVB-T modem.

A second video bitstream can also be multiplexed with the first one by the inner interleaver, when the DVB modem is in its so-called hierarchical mode [1]. The choice of modulation constellations in this mode is between 16-QAM and 64-QAM. We shall be employing this transmission mode, when the so-called data partitioning scheme is used to split the incoming MPEG-2 video bitstream into two classes of data, with one class having a higher priority than the other one. The higher priority data will be multiplexed to the most significant bits (MSBs) of the modulation constellation points and the lower priority data to the least signifi-

ISBN 968-36-7763-0 / 22-25 May 2000 © ICT 2000

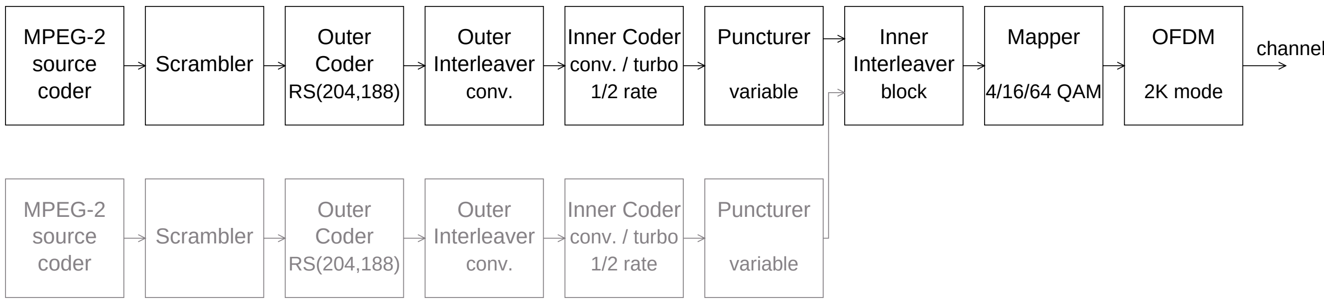


Figure 1: Schematic of the DVB terrestrial transmitter functions.

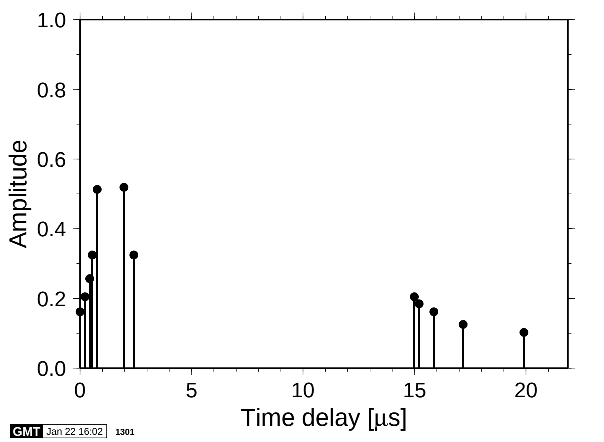


Figure 2: COST 207 hilly terrain (HT) type impulse response.

cant bits [6] (LSBs). For 16-QAM and 64-QAM, the upper 2 bits of each 4- or 6-bit symbol will contain the more important video data. The lower priority data will then be multiplexed to the lower significance 2 bits and 4 bits of 16-QAM and 64-QAM, respectively.

Rate	1/2
Input block length	17952 bits
Interleaver	random
Number of iterations	8
Constraint Length	3
k	1
n	2
Polynomials	7,5

Table 2: Parameters of the inner turbo encoder used to replace the DVB-T system's convolutional coder.

Beside implementing the standard DVB-T system as a benchmarker, we have improved the system by replacing the convolutional coder by a turbo codec [8]. The turbo codec's parameters used in the experiment are displayed in Table 2. Let us now briefly consider the multipath channel model used in our experiments.

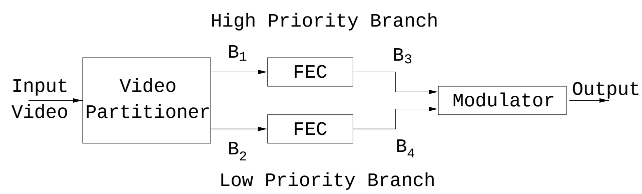


Figure 3: Video partitioning scheme for the DVB-T system operating in hierarchical mode.

In the system characterised here, we have used a carrier frequency of 500MHz and a sampling rate of $7/64\mu$s. The channel model employed in this study was the twelve-path COST 207 [9] hilly terrain (HT) type impulse response, with a maximal relative path delay of 19.9 μs. Each of the paths was faded independently obeying a Rayleigh fading distribution, according to a normalised Doppler frequency of 10^{-5}. This corresponds to a worst-case vehicular velocity of about 200 km/h. The unfaded impulse response is depicted in Figure 2. In order to facilitate un-equal error protection, let us now consider, how to partition the video data stream.

3. PERFORMANCE OF DATA PARTITIONING

The schematic of the hierarchical data partitioning scheme employed in seen in Figure 3. Let us refer to the equally split rate-1/2 convolutional coded high and low priority scenario as Scheme 1. Furthermore, the rate-1/3 convolutional coded high priority data and rate-2/3 convolutional coded low priority data based scenario is referred to here as Scheme 2. Lastly, the rate-2/3 convolutional coded high priority data and rate-1/3 coded low priority data based partitioning scheme is termed as Scheme 3. The associated so-called priority breakpoint [1] (PBP) histograms are shown in Figures 4(a), 5(a) and 6(a). Comparing the histograms in Figure 4(a), 5(a) and Figure 6(a), we observed that as expected, Scheme 3 had the most data in the high priority partition, followed by Schemes 1 and 2.

We then embarked on quantifying the error sensitivity of the partitioning Schemes 1 to 3, when subjected to randomly distributed bit errors. The Peak Signal-to-noise Ratio (PSNR) was used as our video quality measure, which

ISBN 968-36-7763-0 / 22-25 May 2000 © ICT 2000

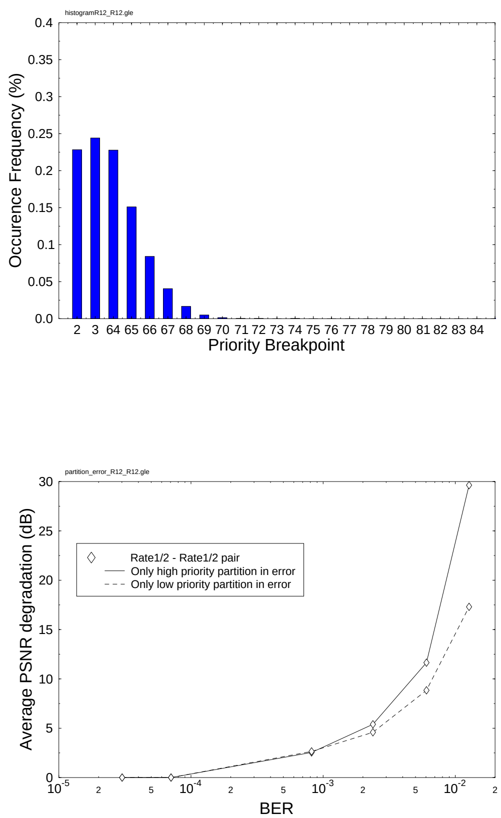


Figure 4: (a) Histogram of the probability of occurence for various priority breakpoints and (b) average PSNR degradation versus BER for rate-1/2 convolutional coded high and low priority data in Scheme 1.

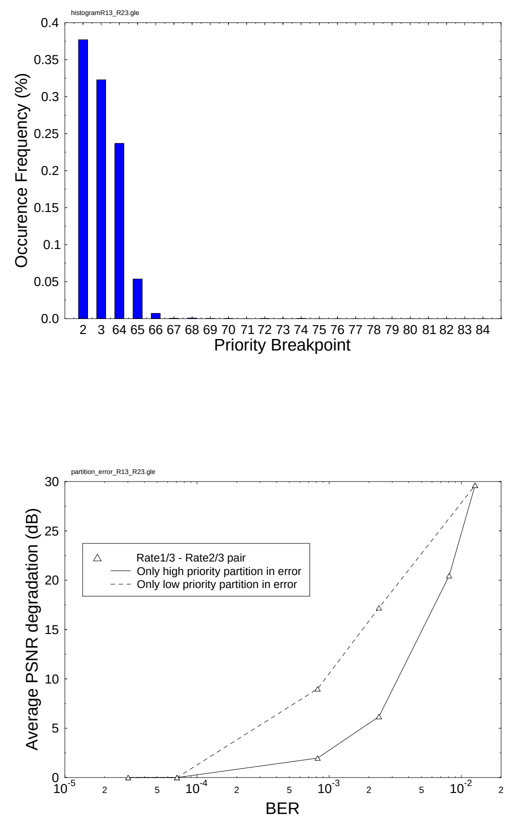


Figure 5: (a) Histogram of the probability of occurence for various priority breakpoints and (b) average PSNR degradation versus BER for the rate-1/3 convolutional coded high priority data and rate-2/3 convolutional coded low priority data in Scheme 2.

was defined as:

$$\text{PSNR} = 10log_{10}\frac{\sum_{n=0}^{N}\sum_{m=0}^{M}255^2}{\sum_{n=0}^{N}\sum_{m=0}^{M}\Delta^2} \qquad (1)$$

where Δ is the difference between the uncoded pixel value and the reconstructed pixel value.

Specifically, the average PSNR degradation was evaluated for given error probabilities inflicting random errors imposed on one of the partitions, while keeping the other partition error-free. These results are portrayed in Figures 4(b), 5(b) and 6(b), for Schemes 1 to 3. Due to lack of space the interpretation of these results is left for the reader. In the next section we will provide overall system performance results.

4. PERFORMANCE OF THE DVB TERRESTRIAL SCHEME EMPLOYING HIERARCHICAL TRANSMISSION

Below we will invoke the DVB-T hierarchical scheme in a mobile broadcasting scenario. We shall also show the improvements which turbo codes offer, when replacing the convolutional code in the standard scheme. Hence, the convolutional codec in both the high and low priority partitions was replaced by the turbo codec. We have also investigated replacing only the high priority convolutional codec with the turbo codec, pairing the 1/2-rate turbo codec in the high priority partition with the convolutional codec in the low priority partition. Such a hybrid arrangement would constitute a reduced-complexity compromise scheme. Again, the "Football" sequence was used in these experiments.

The performance of the investigated mobile video broadcast system is characterised with the aid of Figures 7 and 8, the exploration of which is left for the reader due to lack of space. A specific problem faced, when using the data partitioning scheme in conjunction with the high priority partition being protected by the rate 1/2 code and the low priority partition protected by the rate 3/4 and 7/8 codes was that when the low priority partition data was corrupted, the error-free high priority data available was insufficient for concealing the errors. We have also experimented with the combination of rate 2/3 convolutional coding and rate 1/2

ISBN 968-36-7763-0 / 22-25 May 2000 © ICT 2000

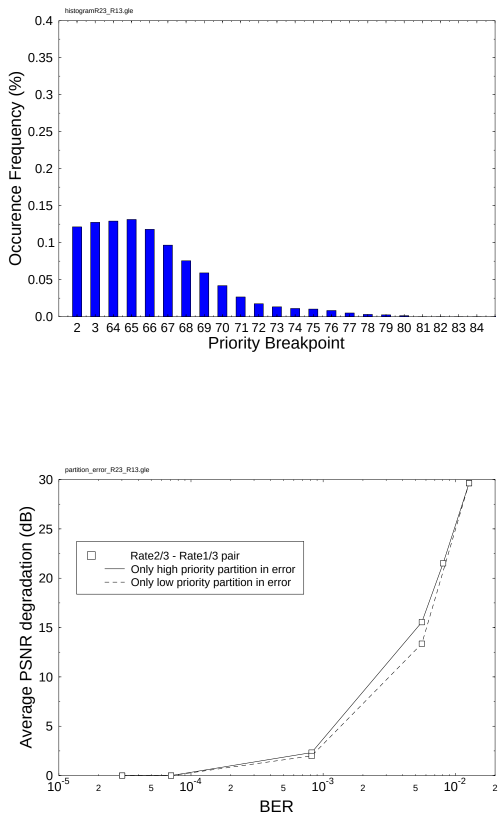
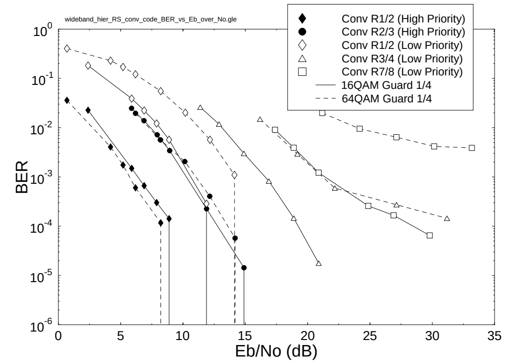
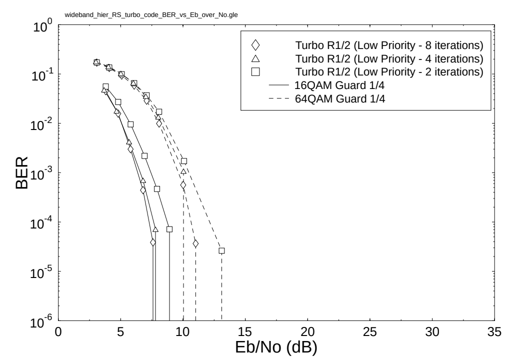


Figure 6: (a) Histogram of the probability of occurence for various priority breakpoints and (b) average PSNR degradation versus BER for the rate-2/3 convolutional coded high priority data and rate-1/3 convolutional coded low priority data in Scheme 3.



(a) RS and Convolutional Code



(b) RS and Turbo Code

Figure 7: BER after (a) RS and convolutional decoding and (b) RS and turbo decoding for the DVB-T hierarchical scheme over the wideband fading channel of Figure 2 using the schematic of Figure 3.

convolutional coding, in order to protect the high and low priority data, respectively. From Figure 8(a) we observed that the performance of this combination approached that of the rate 1/2 convolutional code in both partitions. This was expected, since now more data can be inserted into the high priority partition. Hence, in the event of decoding errors in the low priority data we had more error-free high priority data that can be used to reconstruct the received image.

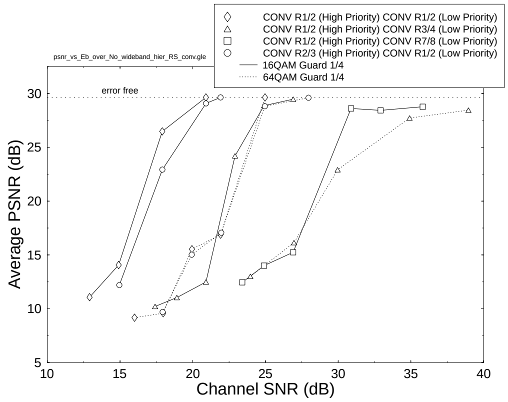
Our last combination investigated involved using rate 1/2 turbo coding and convolutional coding for the high- and low-priority partitions, respectively. Comparing Figures 9 and 8(a), the channel SNR required for achieving error free transmission in both cases were similar. This was expected, since the turbo-convolutional combination's performance is dependent on the convolutional code's performance in the low priority partition.

Lastly, comparing Figures 8 and 10, we found that the error-free condition was achieved at similar channel SNRs suggesting that the data partitioning scheme had not provided sufficient performance improvements in the context of the mobile DVB scheme, in order to justify its added complexity.

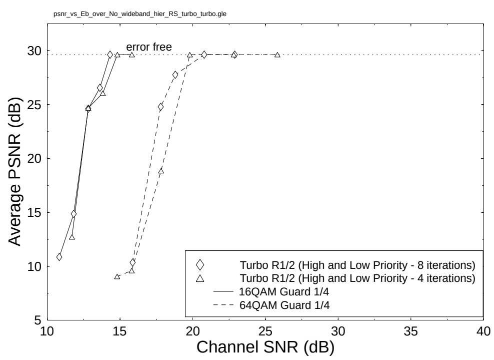
5. CONCLUSIONS AND FUTURE WORK

In this paper, we have investigated the performance of a turbo-coded DVB system in a mobile environment. A range of system performance results was presented based on the standard scheme as well as on a turbo-coded scheme. The convolutional code specified in the standard system was substituted with turbo coding, which resulted in a substantial coding gain of around 5 dB, which can be invested in employing a higher-throughput, less robust modulation mode, such as 16QAM. This then allows us to double the associated bitrate within a given bandwidth, resulting in improved video quality. We have also applied data partitioning to the MPEG-2 video stream in order to gauge its effectiveness in increasing the error resilience of the video

ISBN 968-36-7763-0 / 22-25 May 2000 © ICT 2000



(a) Standard Scheme



(b) Turbo Code in both partitions

Figure 8: Average PSNR versus channel SNR for (a) standard DVB scheme [1] and (b) system with turbo coding employed in both partitions, for transmission over the wideband fading channel of Figure 2 for hierarchical transmission using the schematic of Figure 3.

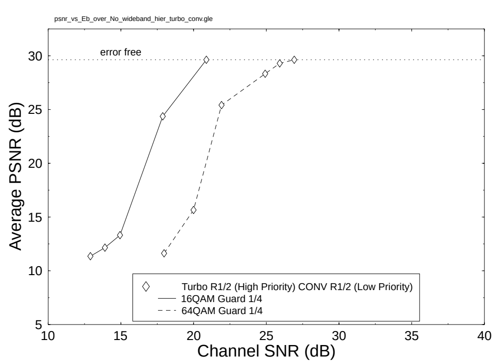


Figure 9: Average PSNR versus channel SNR of the DVB scheme, employing turbo coding in the high priority partition and convolutional coding in the low priority partition, over the wideband fading channel of Figure 2 for hierarchical transmission using the schematic of Figure 3.

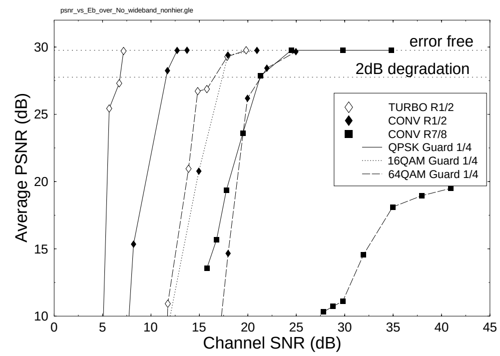


Figure 10: Average PSNR versus channel SNR of the DVB scheme [1] over the wideband fading channel of Figure 2 for non-hierarchical mobile transmission.

codec. However, from these experiments we found that the data partitioning scheme did not provide substantial improvements compared to the non-partitioned video transmitted over the non-hierarchical DVB-T system. Our future work will be focused on improving the system's robustness by invoking a range of so-called maximum-minimum distance Redundant Residue Number System (RRNS) codes and turbo BCH codes. For more detail on DVB the interested reader is referred to [10].

6. REFERENCES

[1] ETSI, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television*, August 1997. EN 300 744 V1.1.2.

[2] ETSI, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems*, December 1997. EN 300 429 V1.2.1.

[3] ETSI, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz Satellite Services*, August 1997. EN 300 421 V1.1.2.

[4] R. Steele and L. Hanzo, eds., *Mobile Radio Communications*. John Wiley & Sons, 2 ed., 1999.

[5] A. M. Michelson and A. H. Levesque, *Error Control Techniques for Digital Communication*. Wiley-Interscience, 1985.

[6] L. Hanzo, W. Webb, and T. Keller, *Single and multicarrier quadrature amplitude modulation*. John Wiley & Sons and IEEE Press, 2000.

[7] P. Shelswell, "The COFDM modulation system: the heart of digital audio broadcasting," *Electronics & Communication Engineering Journal*, vol. 7, pp. 127–136, June 1995.

[8] C. Berrou, A. Glavieux, and P. Thitimajshima, "Near Shannon limit error-correcting coding and decoding: Turbo codes," in *Proceedings of the International Conference on Communications*, pp. 1064–1070, May 1993.

[9] M. Failli, "Digital land mobile radio communications COST 207," tech. rep., European Commission, 1989.

[10] L. Hanzo, P. J. Cherriman, and J. Streit, *Modern Video Compression and Communications: Principles and Applications for Fixed and Wireless Channels*. Kluwer Academic Publishers, 1998. to be published.

ISBN 968-36-7763-0 / 22-25 May 2000 © ICT 2000