COMPARISON OF DVB-H LINK LAYER FEC DECODING STRATEGIES IN A MOBILE FADING CHANNEL

Heidi Himmanen[1], Ali Hazmi[2] and Jarkko Paavola[3]

[1,3] Turku Centre for Computer Science (TUCS)
University of Turku
Lemminkäisenkatu 14 A, FI-20520 Turku
Finland
[1]heidi.himmanen@utu.fi, [3]jarkko.paavola@utu.fi

[2] Institute of Communications Engineering
Tampere University of Technology
P.O.Box 533, FI-33101 Tampere
Finland
ali.hazmi@tut.fi

ABSTRACT

DVB-H offers reliable high data rate reception for mobile handheld and battery-powered devices. A link layer with error correction is defined to work on top of the DVB-T physical layer. The DVB-H standard suggests to use Reed-Solomon coding combined with cyclic redundancy check error detection as the link layer forward error correction. However, there exist more powerful methods for decoding. In this paper, a detailed comparison of five different decoding strategies is presented of which all are compatible with the current standard. Comparison is based on frame error, IP packet error and byte error rates after decoding. Also, the effect of errors on visual experience of a video stream is analyzed.

Keywords: DVB-H, Reed-Solomon, error decoding, erasure decoding, simulation

I. INTRODUCTION

Digital Video Broadcasting for Handheld reception (DVB-H) [1] is a standard for delivery of Internet Protocol (IP) based services to battery powered mobile receivers and was ratified by European Telecommunications Standards Institute (ETSI) in November 2004. A good overview of the DVB-H technology is given in [2].

DVB-H is an amendment of the terrestrial DVB standard (DVB-T) [3], thus changes were needed to enable better mobile performance, low power consumption, compatibility with IP networks and more flexibility in network planning. The approach to combat the effects of receiver mobility is a Reed-Solomon link layer forward error correction (FEC) code denoted with RS(255,191). To facilitate error detection in the receiver, a cyclic redundancy check (CRC) is also performed for sections of encoded RS data. The standard does not define the decoding method of the link layer but suggests the erasure decoding scheme, where RS(255,191) is combined with CRC-32. The physical layer of DVB-H is described in detail in [3] and the link layer in [4].

Previous research has shown that the decoding scheme utilizing CRC information for error detection as suggested in the DVB-H standard is inefficient, since a great amount of correctly received bytes are lost. In [5] it is concluded that more efficient methods to utilize signalling overhead caused by CRC or more powerful decoding methods should be sought. A decoding algorithm for the DVB-H link layer called *hierarchical decapsulation and decoding* is presented in [6] (originally in [7]). The algorithm makes use of all received data to enable more powerful decoding as opposite to the method presented in [4], where erroneous data is simply discarded.

This paper compares five different decoding methods for the DVB-H link layer FEC: section erasure (SE), conventional non-erasure (NE), transport stream erasure (TSE), hierarchical section erasure (HSE) and hierarchical transport stream erasure (HTS).

The paper is organized as follows: DVB-H link layer as defined in [4] is presented in section II. In section III, the compared decoding methods are presented in detail. The different decoding approaches are compared in section IV with computer simulations. Finally, concluding remarks are given in section V.

II. THE DVB-H LINK LAYER

A conceptual diagram of the DVB-H system is illustrated in Fig. 1. The physical layer consists of the DVB-T modulator and demodulator and the link layer consists of the IP encapsulator and decapsulator. DVB-H services can optionally share mux with DVB-T services as presented in Fig. 1. Operations performed by DVB-H link layer are illustrated in Fig. 2.

The size of the MPE-FEC frame is service independent. The number of rows can be 256, 512, 768 or 1024, depending on the wanted burst size. The number of data columns is 1-191 and the number of redundancy columns is 0-64. The IP datagrams are encapsulated column-wise into the MPE-FEC frame and the data are encoded row-wise using RS(255,191) code. Different MPE-FEC code rates are achieved with code shortening and puncturing. The code rate is 3/4 if all 191 data columns and 64 redundancy columns are used. Other conceivable code rates are 1/2, 2/3, 5/6 and 7/8.

The frame is divided into sections so that an IP datagram forms the payload of an MPE-section and a redundancy column form the payload of a FEC-section. When the section header is attached, the CRC-32 redundancy bytes are calculated for the section. The sections are transmitted in a MPEG-2 transport stream (TS) format [8], where a TS packet consists of a 4-5 byte TS header and 183-184 bytes of payload. This procedure is illustrated in Fig. 2. The MPEG-2 format for transport packets is inherited from DVB-T to ensure the compatibility of DVB-H with the existing DVB-T networks.

The receiver performs decapsulation of the received transport stream. The sections are decapsulated into the MPE-FEC frame. The decoding method is not defined but [4] suggests to use erasure decoding, which is presented in section III-A.

1-4244-0330-8/06/$20.00©2006 IEEE

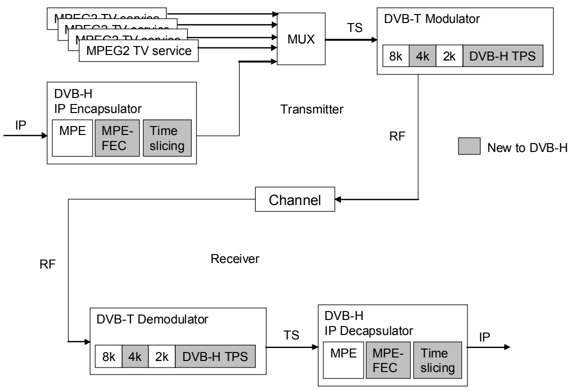

Figure 1. A conceptual description of the DVB-H system [1]

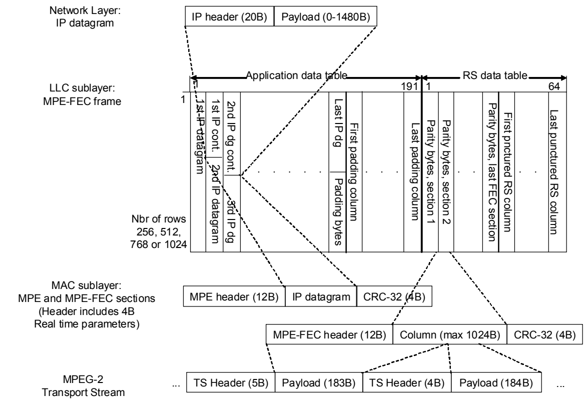

Figure 2. The link layer packets of DVB-H

III. DIFFERENT DECODING APPROACHES FOR DVB-H

In this section five different decoding methods based on erasure decoding, error decoding or a combination of these are presented. It is known [9, 10] that any code of distance d corrects for sure t_e erasures and t_u errors whenever

$$t_e + 2t_u < d \qquad (1)$$

For RS codes the distance d equals to the number of redundancy bytes plus one. If pure erasure decoding is used, the amount of corrected erasures equals the amount of redundancy bytes available. For pure error decoding the error correction capability is half of the amount of redundancy bytes. The hierarchical decoding schemes *hierarchical section decoding* and *hierarchical transport stream decoding* were originally presented in [6].

A. Section erasure decoding (SE)

Section erasure decoding is the combination of Reed-Solomon coding with Cyclic Redundancy Check (CRC-32) that is the suggested decoding method in the DVB-H standard. The 32 CRC-bits at the end of each section are used for section error detection. Sections, whose CRC check fails, are considered erasures. RS decoding is carried out row-wise. If a row contains more erasures than the number of redundancy bytes, decoding fails. When the IP datagrams can be up to 1500 bytes, a lot of correctly received data are marked as unreliable, when the CRC-32 check fails.

B. Hierarchical section erasure decoding (HSE)

1) Hierarchical decapsulation of sections

Hierarchical decoding starts with hierarchical decapsulation. The aim is to also decapsulate erroneous data into the MPE-FEC frame, since all data can be useful for decoding. Sections, whose CRC check is successful, are marked as correct bytes with ‘0’. Sections, whose CRC check fails, but the section can be decapsulated are marked with ‘X’. These sections contain low priority data and cannot overwrite correct data but can be overwritten. Lost sections are marked as erasures with ‘1’.

2) Hierarchical decoding

Hierarchical decoding is carried out in two steps. If pure erasure decoding fails, erasure and error decoding will be performed. Decoding is performed independently on every row of the MPE-FEC frame.

First pure erasure decoding is performed. All bytes marked with ‘1’ or ‘X’ are treated as erasures. If a row contains more erasures than the number of redundancy bytes, erasure decoding fails. Then we turn to combined error and erasure decoding. Now, only bytes marked with ‘1’ are treated as erasures (t_e). The rest of the distance d of the code is used for error decoding. Bytes marked with ‘X’ are treated as possibly incorrect data that might contain errors (t_u). If the number of erasures and errors fulfil (1), the row can be decoded, else decoding fails.

C. Transport Stream Erasure decoding (TSE)

Transport stream erasure decoding is based on the *transport_error_indicator* (TEI) in the TS packet header. The indicator is a one bit flag that is set to ‘1’ if the physical layer RS(204,188) decoder is unable to decode the TS packet, i.e. there are more than 8 byte errors in the 204-byte codeword. TS packets, whose TEI = ‘1’ are considered erasures along with lost packets and lost sections. Lost packets are those, whose 13 bit *Packet_IDentifier* (PID) is incorrect and the TS packet cannot be recognized as part of the stream. In other words only correct TS packets are considered as correct data. All other data are erasures. If a row contains more erasures than the number of redundancy bytes, decoding fails.

D. Hierarchical Transport Stream decoding (HTS)

In HTS decapsulation bytes carried in reliable TS packets, with TEI =’0’, are marked with ‘0’. Erasures, marked with ‘1’, consists of lost TS packets and lost sections. The low priority data, marked with ‘X’, are erroneous TS packets, whose TEI='1'. In HTS hierarchical decoding is performed the same way as for HSE, described in subsection III-B.

E. Non-erasure decoding

Non-erasure decoding is Reed-Solomon error decoding, where no erasure information is utilized but all bytes are considered as possible errors. Theoretically, the error correction capability is half of the erasure detection capability as shown in (1). However, in erasure decoding also correct bytes are erased, diminishing the performance.

On the other hand, at DVB-H link layer there are an amount of lost TS packets and sections, which may increase the number of errors beyond the error correction capability of pure error decoding. Under such circumstances, hierarchical decoding methods, which consider the possibility of losing data, can perform better.

IV. PERFORMANCE EVALUATION

Simulations were carried out to compare link layer error rates for the decoding methods discussed in section III as a function of the carrier-to-noise ratio (C/N) as it is defined in [3]. MPE-FEC frame error rate (MFER) is the ratio of uncorrected MPE-FEC frames during the observation period and is an established quality criterion in DVB-H [2]. The MFER range chosen for inspection is from 1% to 5%. It is expected that sufficient quality of service for streaming video applications is achieved with MFER smaller than 5%.

If all erroneous frames are discarded, the user could experience long times of blackout during a service. This is undesired especially for streaming video services, where error-free reception is not required. More important than MFER is then to measure IP packet error rate (IP PER) and byte error rate or symbol error rate (SER). [2] also mentions another error criterion Erroneous Seconds Ratio (ESR), defined as the ratio of seconds with errors over the observation period. ESR 5% has shown to be correlated with the subjectively perceived reception quality.

A. Physical layer simulator

Criteria in the selection of simulation parameters were to choose parameters, which are likely to be adopted in commercial systems. The physical layer configurations were: modulation 16QAM, convolutional code rate 1/2, OFDM mode 8K and guard interval 1/4. OFDM mode refers to the size of the FFT (Fast Fourier Transform) component, which determines the number of carriers in the system. Simulations were carried out with Doppler frequencies 10 Hz and 30 Hz.

A computer simulation chain of the DVB-H physical layer [3], illustrated in Fig. 3, was implemented. It comprises a DVB-T/H transmitter, channel and a bit-true DVB-T/H receiver. The MUX and the energy dispersal block in the transmitter can be modelled by a pseudo random binary source generator implemented as a maximum period linear feedback shift register. The binary stream is converted to a byte stream and fed to the outer coder. The other blocks in the transmitter are implemented according to the DVB-T standard

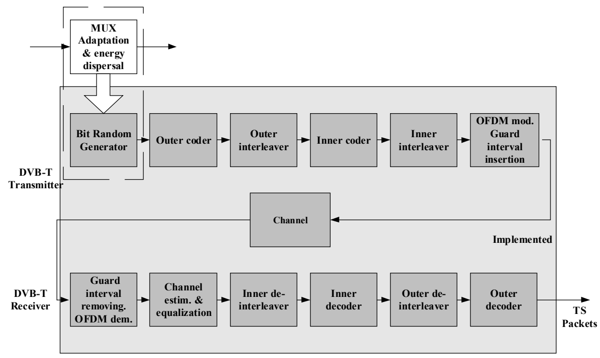

Figure 3. Block diagram of the DVB-T modulator, channel and demodulator.

[3]. The simulated channel can be parameterized so that it allows choosing between several channel profiles. In these simulations the COST207 TU6 [11] six-tap multipath channel corresponding to typical urban propagation conditions was used.

In order to derive estimate for the channel in the receiver scattered pilots are extracted and used in the interpolation of the channel estimates on data subcarriers. Usually, the channel estimation is implemented using two separate interpolation steps, one in the time domain and the other in the frequency domain. With interpolation of all scattered pilots in the time domain, we obtain responses for every three subcarriers. Then, frequency domain interpolation is applied to estimate channel responses for all subcarriers. To reduce complexity, linear interpolation is used in the first step. After equalization, a Viterbi decoder is used to estimate the transmitted bits.

In order to reduce the excessive duration of the bit-true computer simulation, the RS decoder is implemented conceptually. The decoder does not perform actual decoding, but Viterbi decoded bit stream is compared to the transmitted bit stream and a bit-to-byte conversion is performed. RS(204,188) decoder can correct the up to 8 erroneous bytes in each TS-packet with 16 redundancy bytes. Therefore, RS decoder outputs transmitted symbols if there are no more than eight errors. Otherwise the decoder is not able to correct errors. The output of the physical layer simulator is a binary byte error indicator stream measured at the RS-decoder output. This error mask was used as input to the link layer.

B. Link layer simulations

Also at the link layer, parameters, which are likely to be adopted in commercial systems, were chosen. The MPE- FEC frame has 512 rows, the code rate is 3/4, i.e. 191 data columns and 64 RS columns are used. A constant length of 512 bytes for IP datagrams were chosen for simplicity, i.e. one IP datagram is transmitted in one section corresponding to one column of the MPE-FEC frame.

TS packets are lost if their PID is incorrect, since they cannot be recognized as a part of the wanted transport stream. Because of the *continuity_counter* in the TS packet header, lost packets can be discovered and filled with padding. Parsing and decapsulation of the sections, i.e. how to find the sections and put those into the MPE-FEC frame, are pure implementation issues. It is expected that with good parsing methods sections can be parsed, though parts of them might be included in lost TS packets, by using the address of the previous or following sections. It is assumed in these simulations that sections, whose beginning and end are lost, cannot be decapsulated, since the right place in the MPE-FEC table cannot be found. These sections are lost.

1) Frame, Packet and Byte Error Rates

The results are presented as MFER, IP PER and SER in Fig. 4-6 and table 1. Though the gain in MFER is quite small, when comparing HTS decoding to SE decoding, the difference measured in byte error rate is significant. The gain is 1.2 – 1.4 dB when choosing HTS in stead of SE measured in byte error rates. This implies that an erroneous frame or IP packet contains less byte errors with hierarchical decoding than with erasure decoding. Thus, a visible error is most likely less distracting if using hierarchical decoding methods.

When comparing the SER at the link layer input (dashed line in Fig. 6) to the SER after decoding, HTS gives better SER after decoding at 12 dB, when the same is achieved with SE at 14.5 dB.

Table 1. Signal-to-noise ratio [dB] for error rates 1% and 0.1% (*=extrapolated)

Decoding method	Doppler freq. [Hz]	MFER 1%	IP PER 1%	SER 1%	SER 0.1%
SE	10	14.6	14.2	14.2	15.2*
NE	10	15.2	14.3	13.6	15.2
TSE	10	14.5	14.0	13.9	15.2*
HSE	10	14.4	14.0	13.3	14.6
HTS	10	14.2	13.6	12.8	13.9
Unc.	10	-	15.7	14.5	16.6
SE	30	14.0*	13.5	13.5	14.2*
NE	30	14.3	13.7	13.1	14.1
TSE	30	13.7	13.2	13.2	13.8
HSE	30	13.8	13.2	12.7	13.4
HTS	30	13.2*	12.9	12.2	13.0
Unc.	30	-	16.2*	15.2*	-

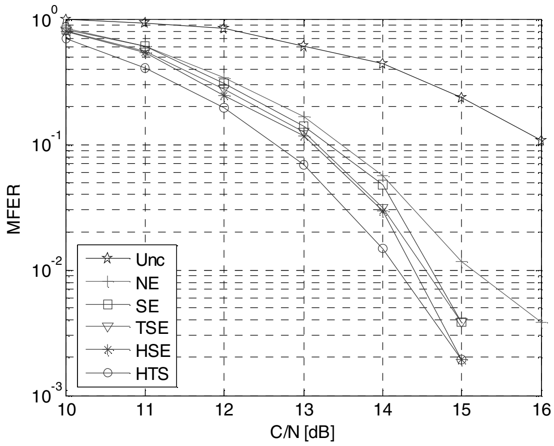

Figure 4. MFER for Doppler frequency 10 Hz

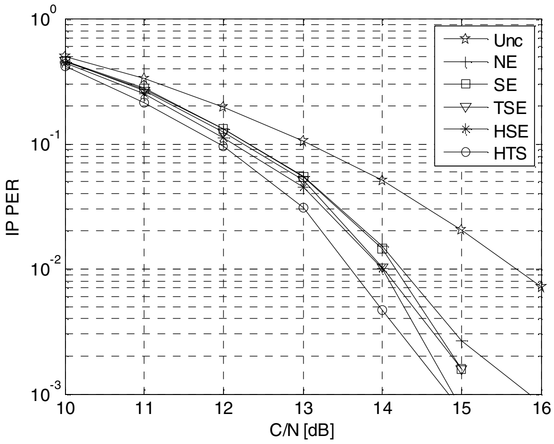

Figure 5. IP PER for Doppler frequency 10 Hz

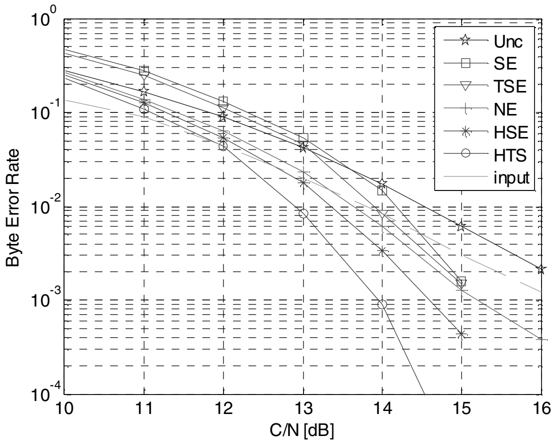

Figure 6. Byte Error Rate for Doppler frequency 10 Hz

2) Erroneous Seconds Ratio (ESR)

A more illustrative study of the video quality is whether the user experiences an error. The advantage of hierarchical decoding and the drawback of erasure decoding are clearly demonstrated when measuring erroneous second ratio (ESR). In Fig. 7-9 the ratios of visible erroneous seconds are presented. The bit rate of the video stream is assumed to be 350 kbps and the image is updated 25 times per second. A visible error is assumed to occur when at least one of the 25 images is erroneous. The error is assumed to be visible when at least half of the bytes of the image are incorrect. The QoS criterion ESR 5% is marked with a solid line in the figures.

Also the ESR analyses show a great advantage of using hierarchical decoding. When comparing HTS and SE decoding, the following conclusions can be made: For 10 Hz Doppler frequency the advantage is of the same range as in the SER analyses. For 30 Hz Doppler frequency the ESR analyses show even greater advantage of using HTS compared to SE. When measuring the gain in decibels, the results correlate with the SER analyses.

On the other hand, when comparing HSE to SE the result is worse in ESR than the SER analyses implies. The ESR analyses show greater difference between HSE and HTS decoding, in favour of HTS. However, ESR only reflects on whether or not an error happened during the second. It does not take into account the severeness of the error to the user experience. In Fig. 8, using HTS or uncoded data, a visible erroneous second contains 60% less erroneous bytes than with SE decoding. Thus, the quality of an erroneous picture also depends on the decoding method.

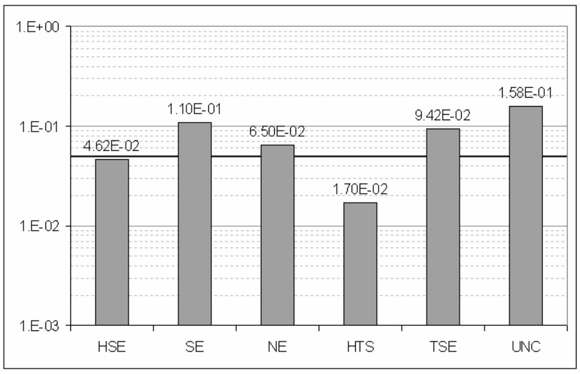

Figure 7. Ratio of visible erroneous seconds, C/N = 13 dB, f_D = 10 Hz (MFER SE ≈ 14%).

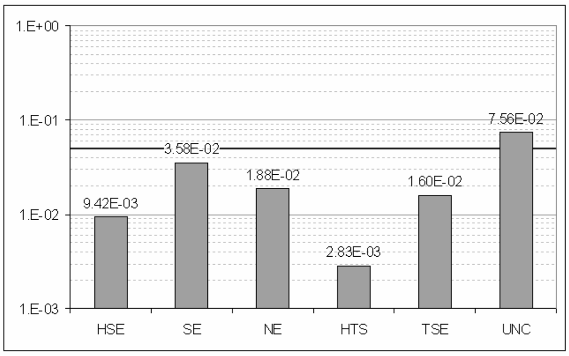

Figure 8. Ratio of visible erroneous seconds, C/N = 14 dB, f_D = 10 Hz (MFER SE ≈ 5%).

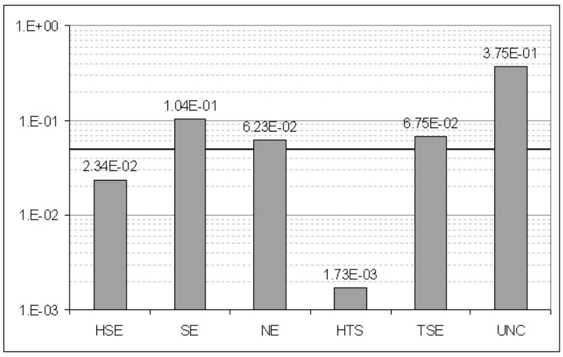

Figure 9. Ratio of visible erroneous seconds, C/N = 13 dB, f_D = 30 Hz (MFER SE ≈ 10%).

V. CONCLUSIONS

Five different link layer decoding methods for DVB-H were compared in this paper using simulations in a mobile channel with multipath fading. To get more accuracy into the analysis, not only the established MPE-FEC Frame Error Rate (MFER) was measured but also IP Packet Error Rate (IP PER), Byte Error Rate (SER) and Erroneous Seconds Ratio (ESR). In the ESR measurements only visible errors were considered.

It was shown that the decoding methods, which insert also erroneous data into the MPE-FEC frame, are more efficient than erasure decoding methods suggested in the DVB-H standard. The SER analysis revealed a gain of 1.2 – 1.4 dB in favour of hierarchical transport stream decoding, when compared to section erasure decoding.

Measuring visible erroneous seconds ratio is an attempt to compare the real video quality experienced by the user. Results imply that video quality can be increased significantly when allowing erroneous data to be used for decoding and passed to the application layer rather than using erasure decoding methods, where erroneous IP packets or even MPE-FEC frames are discarded.

REFERENCES

[1] ETSI EN 302 304: "Digital Video Broadcasting (DVB); Transmission System for Handheld Terminals (DVB-H)", European Telecommunication Standard, Nov. 2004.

[2] G. Faria, J.A. Henriksson, E. Stare, P. Talmola, "DVB-H: Digital Broadcast Services to Handheld Devices", *Proc. IEEE* vol. .94, no. 1, pp.194–209, Jan. 2006.

[3] ETSI EN 300 744: "Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for digital terrestrial television", European Telecommunication Standard, Jan. 2004

[4] ETSI EN 301 192: "Digital Video Broadcasting (DVB); DVB specification for data broadcasting", European Telecommunication Standard, Nov. 2004

[5] H. Joki, J. Paavola and V. Ipatov: "Analysis of Reed-Solomon Coding Combined with Cyclic Redundancy Check in DVB-H Link Layer", in *2nd International Symposium on Wireless Communication Systems 2005,* Siena, Italy, Sep. 2005.

[6] H. Joki and J.Paavola, "A Novel Algorithm for Decapsulation and Decoding of DVB-H Link Layer Forward Error Correction", in *2006 IEEE International Conference on Communications*, Istanbul, Turkey, June 2006.

[7] H. Joki, "Modeling of DVB-H Link Layer", M.Sc. thesis, Helsinki University of Technology, Helsinki, Finland, May 2005.

[8] ISO/IEC 13818-1: "Information technology — Generic coding of moving pictures and associated audio information: Systems", Second Edition, Dec. 2000.

[9] R.E. Blahut, *Algebraic Codes for Data Transmission*. Cambridge University Press, 2003.

[10] M. Bossert, *Channel Coding for Telecommunications*. John Wiley & Sons, Chichester, 1999.

[11] COST207, "Digital land mobile communications (final report)", Commission of the European Communities, Directorate General Communications, Information Industries and Innovation, 1989, pp. 135–147.