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Abstract

This deliverable proposes a simulation model for DVB-T/H as described in Activity 2.2 from Workpackage 2 (WP2). The main objective is to generate error traces in order to design better video coding algorithms and better video adaptation algorithms to DVB-T/H dynamic characteristics. Therefore, the error patterns will be used in other WPs, like WP3 and WP4, to assess the coded video performance and rate control strategies for layered video communications over DVB-T/H as well as in the design of decision Playout algorithms.

Keyword list: DVB-T/H simulation, error traces

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WP2_D2.2_DVB-TH network modeling

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Table of Contents

1 Introduction

1.1 Scope

This document is part of WP2 - Channel and Systems Simulation - and relates to Activity 2.2 - DVB-T Modelling.

It has strong relationships to other activities within WP2 as well as to other Work-packages, in particular to WP3 - Robust Scalable Video Communications over Heterogeneous Networks and WP4 - Playout, Terminal and Networks Resource Management and Optimisation.

Deliverable D2.2 is the first and unique document resulting from Activity A1.2. At a later stage (M 18) this document will have a strong influence in the final deliverable from WP2 - Network Capacity.

Obviously, it is expected that this deliverable results will contribute to exploitation and dissemination activities, WP7.

1.2 Objective

The main objective of this deliverable is to model the network behaviour. The models of DVB-T/H described in this document can be used under different channel conditions and therefore will show enough flexibility to be used in WP2, Activity 2.5, to determine the optimal IP packet length and in WP3 and WP4 so as to design optimal scalable contents and resource allocation, respectively. The models will take into account the DVB-T/H link and physical layer specifications. Thus, based on error traces generated by this activity, A2.2, as well as A2.3 and A2.4, several algorithms will be evaluated in WP3.

This document describes the DVB-T/H [1][2] system and discusses its performance over radio channels models proposed in Deliverable D2.1- Fixed and Mobile Channels.

Before moving to the next Section, we present the SUIT architecture where we can identify the DVB-T/H system.

Deliverable D1.4 - Architecture and Reference Scenarios identified three network scenarios, Home, Mobile and MHP-IPTV. The first one, Home, requires a gateway as depicted, below, in Figure 1. The WiFi end-user terminals will be fed via the gateway interfacing to two different wireless broadband last mile networks, WiMAX and DVB-T/H. The gateway informs the playout about the network and terminal characteristics. The playout selects the right network to deliver the unicasted contents and may need to reduce the services bit-rates according to the network conditions. Figure 1 shows two homes and therefore two home gateways. In each home two terminals are connected to each gateway.

SUIT will set up four base stations in two cells, where they will be co-sited in pairs. So, each cell will have one DVB-T/H base station and one WiMAX base station. This network scenario allows us to test different types of services and functionalities. However, it requires four experimental frequencies and the associated licenses in order to perform the field trials. In Mobile Network scenario, the gateway functionalities are moved into the terminals. The mobile terminal can cross different cells.

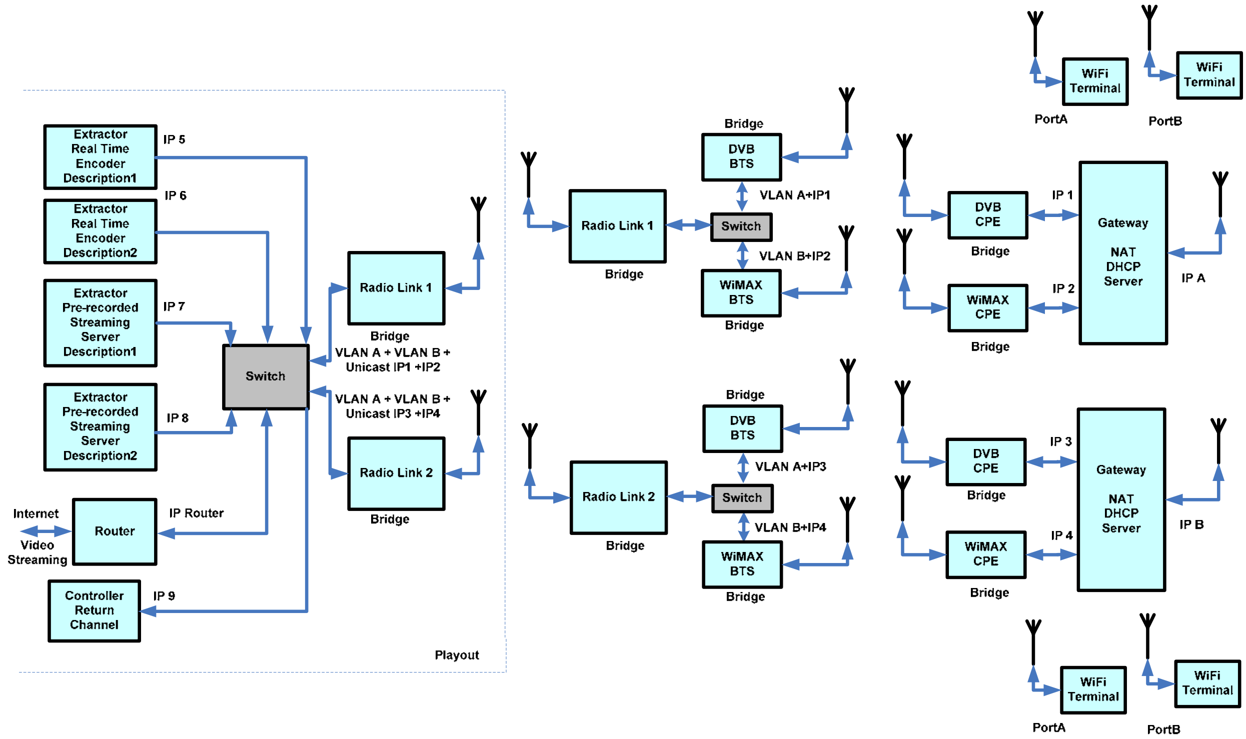

Figure 1: Block diagram of the home network scenario

Deliverable D1.4 also mentioned service scenarios. With the application of new techniques in the SUIT project, various innovating service scenarios will be enabled when converging the two broadband mobile networks IEEE 802.16e (WiMAX), ETSI/EN 300 744 (DVB-T) and ETSI/EN 302 304 (DVB-H). SUIT will deliver a layered description over each of those last mile networks. By using two different video descriptions, SUIT will push video scalability into broadcasting and telecom networks in a fruitful way. The radio interfaces are fed by live scalable contents, pre-recorded scalable contents and internet data. The playout will dynamically and optimally manage all those resources and adapt them according to the network. As a final objective, SUIT intends to demonstrate an end-to-end communication system, from the playout to the terminal, where the terminal can feed an HDTV screen or a small pocket-sized display.

Observing Figure 1, we see a full-duplex DVB-T/H/RCT air connection, one in each cell. Despite the up-link and down-link radio channels are both at UHF, we are just considering in this deliverable, the down-link, DVB-T/H, as the transportation system for broadcasting and unicasting coded video based services.

In Section 2, the DVB-T/H physical layer system is outlined. Section 3 extends the physical and link layers to the packet layer in the context of DVB-H encapsulation and coding strategies. Section 4 presents the results of DVB-T/H physical layer performance with different settings and different channel models. Finally, some conclusions are drawn in Section 5.

2 DVB-T/H Physical Layer Description

DVB-T [2]was the antecessor of DVB-H [1]. DVB-T basically consists of two FEC Codecs, two interleavers and an OFDM modulator as depicted in Figure 2.

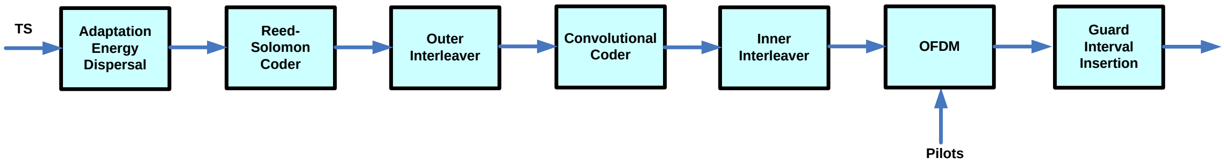

Figure 2: Suit overall architecture

Strictly speaking, DVB-T has the following modules:

- transport multiplex adaptation and randomization for energy dispersal;
- outer coding (i.e. Reed-Solomon code);
- outer interleaving (i.e. convolutional interleaving);
- inner coding (i.e. punctured convolutional code);
- inner interleaving;
- mapping and modulation;
- Pilot insertion;
- Orthogonal Frequency Division Multiplexing (OFDM) transmission;
- Guard interval insertion.

DVB-T system is being designed for digital terrestrial television services to operate within the existing VHF and UHF spectrum allocation which was used for analogue transmissions. Therefore, it is required that DVB-T provides sufficient protection against high levels of Co-Channel Interference (CCI) and Adjacent-Channel Interference (ACI) resulting from existing PAL/SECAM/NTSC services. It is also a requirement that the system allows the maximum spectrum efficiency when used within the VHF and UHF bands. Such a requirement can be achieved by utilizing (SFN) operation. However, SUIT is only dealing with Multiple Frequency Network (MFN) operation. We are also not considering hierarchical transmission.

At the physical layer, the new tools incorporated by DVB-H are one more mode, 4k, in addition to the existing 2k and 8k modes and a deeper inner interleaver covering more than 1 OFDM symbol for 2k and 4k modes. Other tools were also included in the link layer like a RS encoder associated to an IP packets interleaver and time slicing. These tools will be discussed in Section 3. The following sections discuss all modules defined in DVB-T.

2.1 *Energy Dispersal*

The input of the system, in Figure 2, is a sequence of Transport Streams (TS) packets. Each TS has 184 bytes payload and 4 bytes header. One header byte is the SYNC byte which is equal to 0xB8 every 8 packets. Other SYNC bytes are equal to 0x47 (see Figure 4). At the start of each 8 packets sequence (!SYNC), the PRBS-Pseudo-Random Binary Sequence generator, shown in

Figure 3, must be initialised by loading the sequence “100101010000000” into the PRBS registers. Therefore, the period of the PRBS sequence is 1503 bytes. As can be observed from Figure 3, the polynomial generator is,

$$1+X^{14}+X^{15}.$$

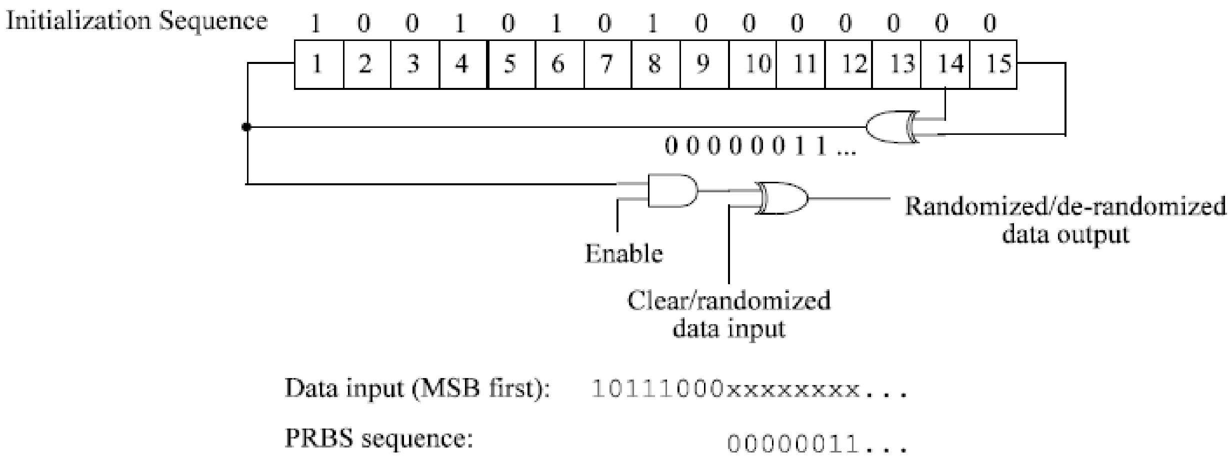

Figure 3: PRBS-Pseudo-Random Binary Sequence generator

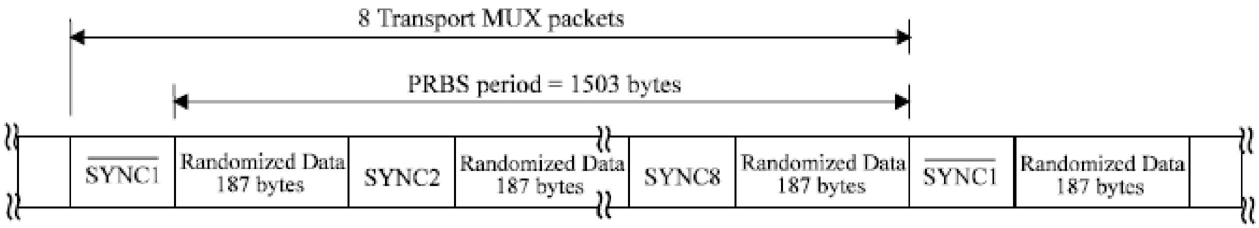

Figure 4: Repetitive sequence of 8 TS packets

2.2 Outer Coder - RS

At this point of the algorithm, Reed-Solomon RS(204,188,t=8) shortened code, derived from the original systematic RS(255,239,t=8) code, shall be applied to each randomized transport packet (188 bytes long), as shown in Figure 4, to generate an error protected packet as shown in the figure below.

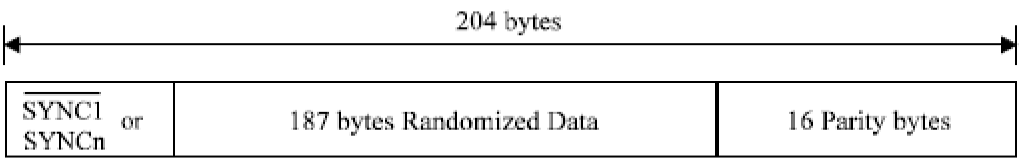

Figure 5: RS packet

RS(204,188,t=8) has the capability of correcting up to 8 random erroneous bytes in 204 bytes. The Reed-Solomon code has length 204 bytes, dimension 188 bytes and allows correcting up to 8 random erroneous bytes in a received word of 204 bytes. The polynomials are:

Code Generator Polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)...(x+\lambda^{15})$, where λ = 0x02

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

The shortened Reed-Solomon code may be implemented by adding 51 bytes, all set to zero, before the information bytes at the input of an RS (255,239, t = 8) encoder. After the RS coding procedure these null bytes shall be discarded, leading to a RS code word of N = 204 bytes.

2.3 Outer Interleaver

According to the DVB-T standard, convolutional byte-wise interleaving with depth I = 12 shall be applied to the RS error protected packets, as shown in Figure 5. This is a Forney approach depitched in Figure 6.

The interleaver is composed of I = 12 branches, cyclically connected to the input byte-stream by the input switch. Each branch j is a First-In, First-Out (FIFO) shift register, with depth j.M cells where M = 17 = N/I, N = 204.

Each cell in the FIFO shall contain 1 byte, and the input and output switches shall be synchronized. For synchronization purposes, the SYNC bytes and the !SYNC bytes shall always be routed in the branch "0" of the interleaver (corresponding to a null delay).

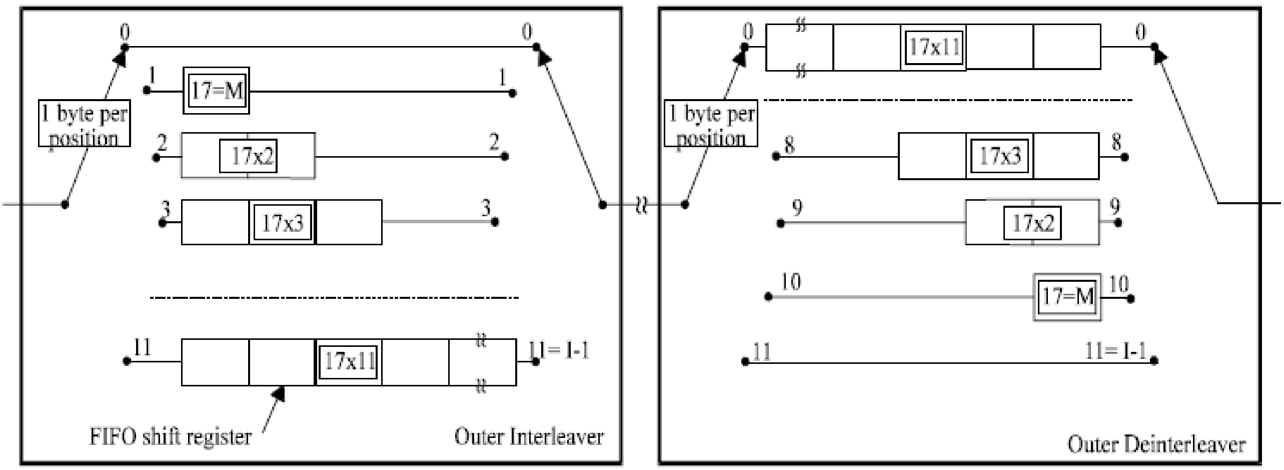

Figure 6:Byte-wise Outer Interleaver and deinterleaver

2.4 Inner Coding - CC

According to DVB-T standard, the system shall allow for a range of punctured convolutional codes, based on a mother convolutional code of rate 1/2 with 64 states. This will allow selection of the most appropriate level of error correction for a given service or data rate. The generator polynomials of the mother code are G1 = 171_{OCT} for X output and G2 = 133_{OCT} for Y output (see Figure 7 below).

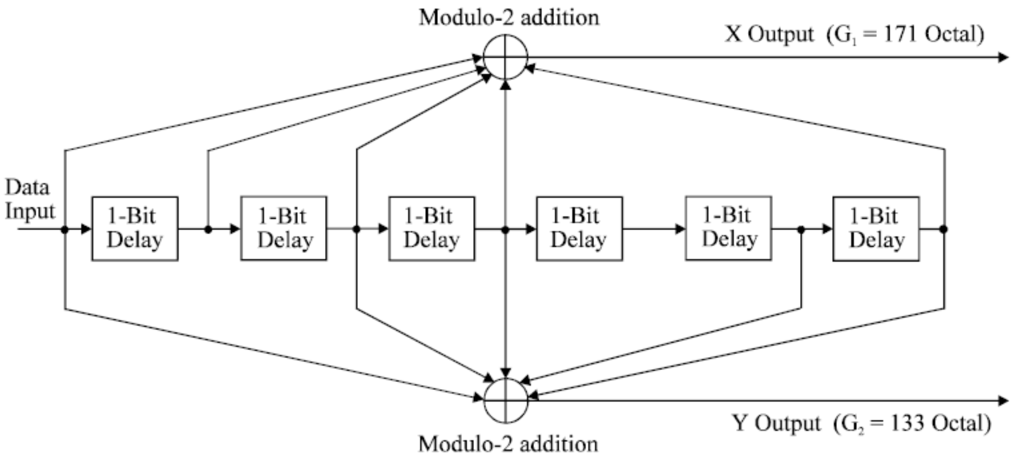

Figure 7: Convolution encoder of ½ code rate

In addition to the mother code of rate 1/2 the system shall allow puncturing to allow higher encoding rate rates of 2/3, 3/4, 5/6 and 7/8. The punctured convolutional code shall be used as given in table below. In this table X and Y refer to the two outputs of the convolutional encoder. '0' means a punctured bit. A Viterbi decoder is used at the receiver side.

Code Rates r	Puncturing Pattern	Serial Transmission
1/2	X:1 Y:1	X1Y1
2/3	X:1 0 Y:1 1	X1Y1Y2
3/4	X:1 0 1 Y:1 1 0	X1Y1Y2X3
5/6	X:1 0 1 0 1 Y:1 1 0 1 0	X1Y1Y2X3Y4X5
7/8	X:1 0 0 0 1 0 1 Y:1 1 1 1 0 1 0	X1Y1Y2Y3Y4X5Y6X7

Table 1: Puncturing table and transmitted sequence after parallel-to-serial conversion for all possible code rates

2.5 Inner Interleaving

The inner interleaving consists of bit-wise interleaving followed by symbol interleaving. Both the bit-wise interleaving and the symbol interleaving are block-based. The bit interleaving block size is 126 bits (so that means we have to wait until we get 126 bits from the inner coding first). The inner interleaver is followed by a symbol interleaver, which for instance in 4K mode, it uses 24 groups of 126 bits (Native 4k) summing 3024 useful bits. The following figure shows the number of groups for all three modes. Bit interleaving is performed only on the useful data (all data coming from the convolutional encoder). We should note that 4k mode has been introduced by DVB-H as a good compromise between cell distance and mobile robustness.

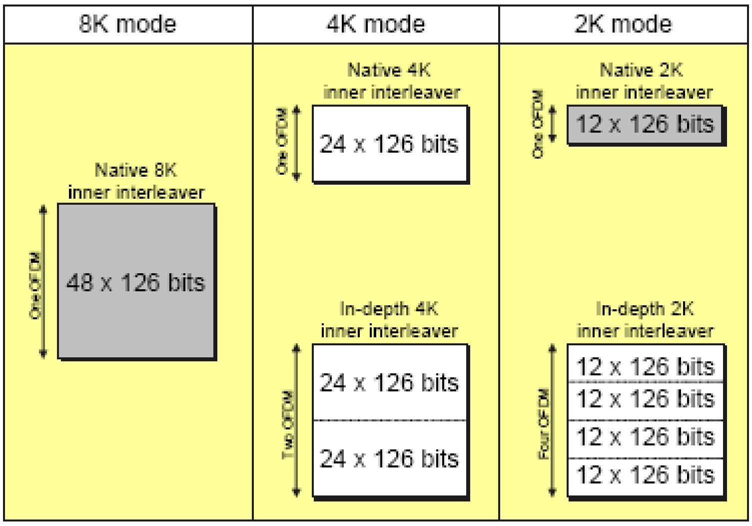

Figure 8: Inner bit interleaver

Considering the particular case the application is using non-hierarchical 64-QAM, the input is demultiplexed into v=6 substreams. To see how this demultiplexing is done, check the figure below.

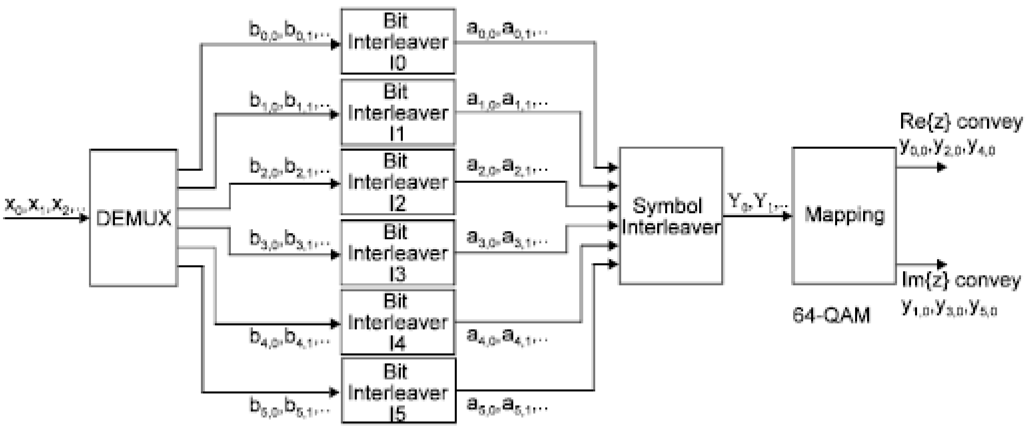

Figure 9: Demultiplexing and Inner bit interleaver

Each Mux input bit is mapped into the input of each 126-bit size buffer , I0,I1,…,I5, following the rules:

X_0 maps to $b_{0,0}$

X_1 maps to $b_{2,0}$

X_2 maps to $b_{4,0}$

X_3 maps to $b_{1,0}$

X_4 maps to $b_{3,0}$

X_5 maps to $b_{5,0}$

Then, it follows the bit interleaving process in each 126-bit buffer. Let the input bit vector be,

$$B(e) = (b_{e,0}, b_{e,1}, b_{e,2}, ..., b_{e,125})$$, where e ranges from 0 to v-1. (e.g. 64-QAM, v=6)

The interleaved output vector,

$$A(e) = (a_{e,0}, a_{e,1}, a_{e,2}, ..., a_{e,125})$$

is defined by,

$$a_{e,w} = b_{e,He(w)},\ w = 0, 1, 2, ..., 125$$

where He(w) is a permutation function which is different for each interleaver. He(w) is defined as follows for each interleaver:

I0: H0(w) = w

I1: H1(w) = (w + 63) mod 126

I2: H2(w) = (w + 105) mod 126

I3: H3(w) = (w + 42) mod 126

I4: H4(w) = (w + 21) mod 126

I5: H5(w) = (w + 84) mod 126

The outputs of the v bit interleavers are grouped to form the digital data symbols (to modulate each subcarrier afterwards) , in which each symbol of v bits will be constructed by extracting one bit from each of the v=6 interleavers. Hence, the output from the bit-wise interleaver is a v=6 bit word y' that has the output of I0 as its most significant bit, i.e.,

$$y'_w = (a_{0,w}, a_{1,w}, ..., a_{v-1,w})$$

The bit interleaver is followed by the symbol interleaver which is responsible by mapping v bit words onto 1512 (2k mode), 3024 (4k mode) and 6048 (8k mode) active carriers per OFDM symbol. The symbol interleaver acts on blocks of 1512 (2k mode), 3024 (4k mode) and 6048 (8k mode) data symbols.

In the 4K mode, 24 groups of 126 data words from the bit interleaver are read sequentially into a vector: $Y' = (y'_0, y'_1, y'_2, ...y'_{1511})$.

The symbol interleaved vector: $Y = (y_0, y_1, y_2, ...y_{Nmax-1})$ is defined by:

$y_{H(q)} = y'_q$ for even symbols for q = 0, ..., Nmax-1

$y_q = y'_{H(q)}$ for odd symbols for q = 0, ..., Nmax-1

Nmax = 1 512 (in the 2K mode).

H(q) is a permutation function defined by the following:

An (Nr - 1) bit binary word R'_i is defined, with Nr = log2 Mmax, where Mmax = 2 048 in the 2K mode, Mmax = 4 096 in the 4K mode and Mmax = 8 192 in the 8K mode where R'_i takes the following values:

i = 0,1: R'_i [Nr-2, Nr-3, ..., 1, 0] = 0, 0, ..., 0, 0

i = 2: R'_i [Nr-2, Nr-3, ..., 1, 0] = 0, 0, ..., 0, 1

2 < i <Mmax: R'_i [Nr-3, Nr-4, ..., 1, 0] = R'_{i-1} [Nr -2, Nr -3, ..., 2, 1];

in the 2k mode, $R'_i[9] = R'_{i-1}[0] \oplus R'_{i-1}[3]$. Other modes, see the standard.

A vector R_i is derived from the vector R'_i by the bit permutations given in below:

R'_i bit positions	9	8	7	6	5	4	3	2	1	0
R_i bit positions	0	7	5	1	8	2	6	9	3	4

Table 2: Bit permutation for 2k mode

R'_i bit positions	10	9	8	7	6	5	4	3	2	1	0
R_i bit positions	7	10	5	8	1	2	4	9	0	3	6

Table 3: Bit permutation for 4k mode

In a similar way to y’, y is made up of v bits,

$$y_{q'} = (y_{0,q'}, y_{1,q'}, y_{2,q'}, \ldots y_{v-1,q'})$$

where q' is the symbol number at the symbol interleaver output. These values of y will be used to map the signal constellation as described in the following section.

2.6 Signal Constellations and Mapping

The exact values of the constellation points are z = {n + j*m} with values of n, m given below for 64-QAM (non-hierarchical with $\alpha = 1$):

n = {-7, -5, -3, -1, 1, 3, 5, 7}, m = {-7, -5, -3, -1, 1, 3, 5, 7}

Figure 10 shows the constellation points, where each v bit word coming from the inner interleaver is mapped onto the complex number z.

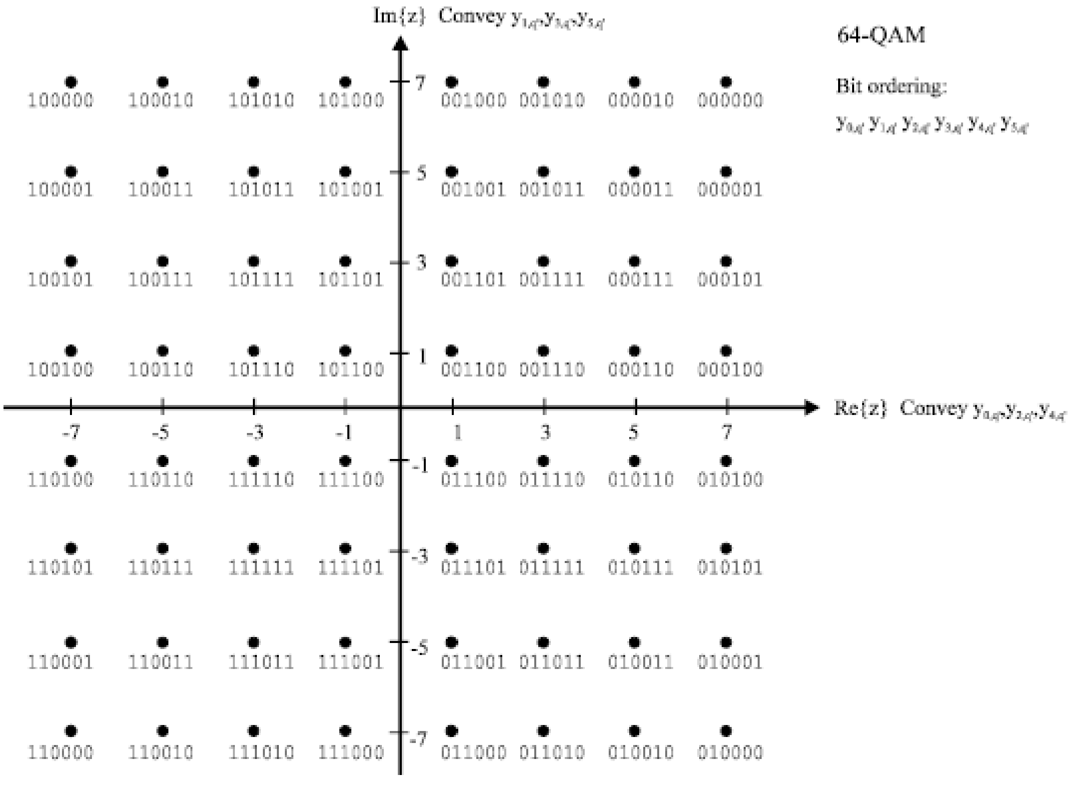

Figure 10: 64-QAM mapping and corresponding bit patterns

2.7 Modulation – OFDM

After the mapping is done, two more operations will be carried out on the obtained complex numbers: organize them into an OFDM frame (and eventually add padding zeroes) and apply the IFFT (Inverse Fast Fourier Transform).

According to the DVB-T standard, the transmitted signal is organized into frames. Each frame consists of 68 OFDM symbols. Four frames constitute one super-frame. Each symbol is composed by a set of K = 1705 carriers (in the 2K mode), K = 3024 carriers (in the 4K mode) or K = 6048 carriers (in the 8K mode), but in order to be able to apply IFFT later, padding zeroes are inserted until we get “packets” of 2048 complex numbers. The symbols in an OFDM frame are numbered from 0 to 67.

In addition to the transmitted data, an OFDM frame also contains:

- Scattered pilot cells;
- Continual pilot carriers;
- TPS carriers.

Some of those pilots are used for equalization purpose. In our study, we are not considering pilots, since we will assume perfect channel estimation. However, any further information from pilots can be obtained from the standard.

2.8 Guard Interval

One from 4 possible guard intervals is inserted, in the beginning of each symbol, after applying IFFT in order to avoid Inter Symbol Interference (ISI). The following two tables show several parameters for 4k mode. Regardless the mode, 2k, 4k or 8k, the elementary period T is 7/64 µs for 8 MHz channels, 7/56 µs (1/8 µs) for 7 MHz channels, 7/48 µs for 6 MHz channels and 7/40 µs for 5 MHz channels. Let us assume 8 MHz channels from now on.

Frequency domain parameters for 8 MHz channels	**8k mode**	**4k mode**	**2k mode**
Number of carriers K	6817	3409	1705
Value of carrier number K_{min}	0	0	0
Value of carrier number K_{max}	6816	3408	1704
Elementary Period T	7/64	7/64	7/64
Duration T_U	896 µs	448 µs	224 µs
Carrier spacing $1/T_U$	1 116 Hz	2 232 Hz	4 464 Hz
Spacing between carriers K_{min} and K_{max}(K-1)/ T_U	7.61 MHz	7.61 MHz	7.61 MHz

Table 4: Frequency parameters for 8 MHz channels

Time Domain Parameters	**8k mode**				**4k mode**				**2k mode**			
Guard interval Δ/T_U	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
Duration of symbol part T_U	8 192 x T 896 µs				4 096 x T 448 µs				2 048 x T 224 µs			
Duration of guard interval Δ	2048 x T 224 µs	1024 x T 112 µs	512 x T 56 µs	256 x T 28 µs	1024 x T 112 µs	512 x T 56 µs	256 x T 28 µs	128 x T 14 µs	512 x T 56 µs	256 x T 28 µs	128 x T 14 µs	64 x T 7 µs
Symbol duration $Ts=\Delta+T_U$	10240 x T 1120 µs	9216 x T 1008 µs	8704 x T 952 µs	8448 x T 924 µs	1024 x T 560 µs	512 x T 504 µs	256 x T 476 µs	128 x T 462 µs	2560 x T 280 µs	2304 x T 252 µs	2176 x T 238 µs	2112 x T 231 µs

Table 5: Time parameters for 8 MHz channels

2.9 Radio Channels

Radio channels were studied in deliverable D2.1 [3]. Radio channels are divided into fixed or static channels and mobile or dynamic channels. The DVB-T/H simulator developed in SUIT is flexible and can cope with both cases. In D2.1, Sections 3.1.1 and 3.1.2 identified several fixed and mobile channels, respectively, from COST207 and extended COST231.

3 DVB-H Encapsulation and Coding

DVB-H [1] is based on DVB-T and basically re-uses the well-known DVB-T transmission parameters, inheriting the DVB-T flexibility and performance, but offering additional delivery methods to extend the traditional trade-off between bit rate capacity and ruggedness. The terrestrial DVB-T standard [2] with some additional features is used at the physical layer as mentioned in Section 2. The main technological changes have been made on the link layer.

Figure 11 shows a block diagram of the FEC coding schemes used on DVB-H.

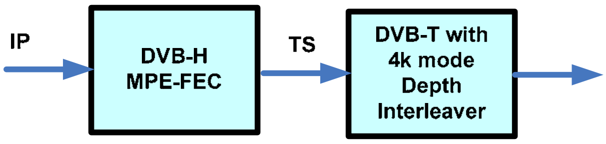

Figure 11: Block diagram showing the FEC coding schemes used on DVB-H

DVB-H services are based upon the Internet Protocol (IP) which means that highly compressed Audio/Visual (A/V) information is carried in IP-datagrams. The data payload of DVB-H is in IP packet form, which makes the system suitable for a variety of services in addition to streaming video.

Due to the small form factor of hand-held devices and their possible use in mobile environments (DVB-H terminals are expected to be used in various situations of reception: indoor/outdoor while the user is static, pedestrian or mobile), the signal reception will suffer from both low Carrier-to-Noise Ratio (CNR) and multipath fading with Doppler.

Since the IP datagrams carry highly compressed A/V information, it is very important to restore as many IP datagrams as possible. Therefore, in order to make the reception more robust, an extra layer of Forward Error Correction (also known as MPE-FEC) was added to the link layer of DVB-T: IP-datagrams are encapsulated in the MPEG-2 transport stream using Multi-Protocol Encapsulation (MPE) sections and the IP datagrams belonging to a time-slice are protected with a (255,191) Reed-Solomon (RS) code. The resulting parity data is multiplexed in the MPEG-2 transport stream using MPE-FEC sections referred above and it is transmitted in the same time-slice.

In the next section it is explained how MPE-FEC encapsulation and coding can be established as proposed in ETSI EN 301 192, v.1.4.1[4].

3.1 Encapsulation and Coding

The DVB-H system implements technical components spread over the physical layer, the data link layer and the control layer of the DVB standard portfolio. Regarding the data link layer [4][5], DVB-H intends to increase the robustness of the service transmission and for this purpose it was defined an additional error protection, by a combination of MPE and FEC based on Reed Solomon Forward Error Protection codes, applied at the data link layer level for better tolerance of radio interference and Doppler effects.

The structure of data link layer frame is illustrated in Figure 12.

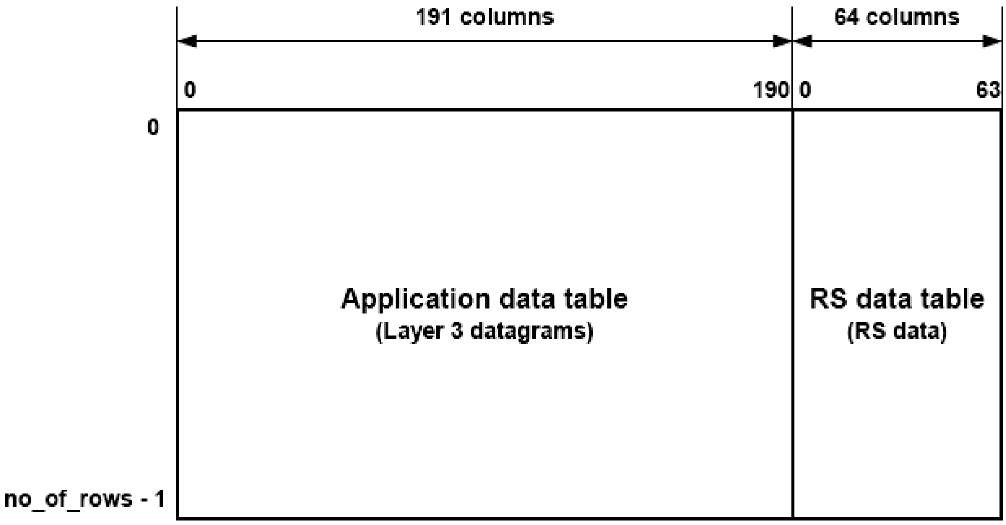

Figure 12: *The structure of the MPE-FEC Frame.*

The MPE-FEC frame is arranged as a matrix with 255 columns and a flexible number of rows which maximum allowed value is 1024 (2 *Mbit* array, the number of rows depends on the length of the IP datagrams). The 191 leftmost columns are called “Application Data Table” and are assigned to layer 3 (Network layer) datagrams. Therefore, the services IP datagrams are stored in a matrix made of 191 columns up to 1024 rows. The 64 rightmost columns are called “RS Data Table” and are dedicated for the parity information. Therefore, the RS parity data is stored in a matrix made of 64 columns up to 1024 rows.

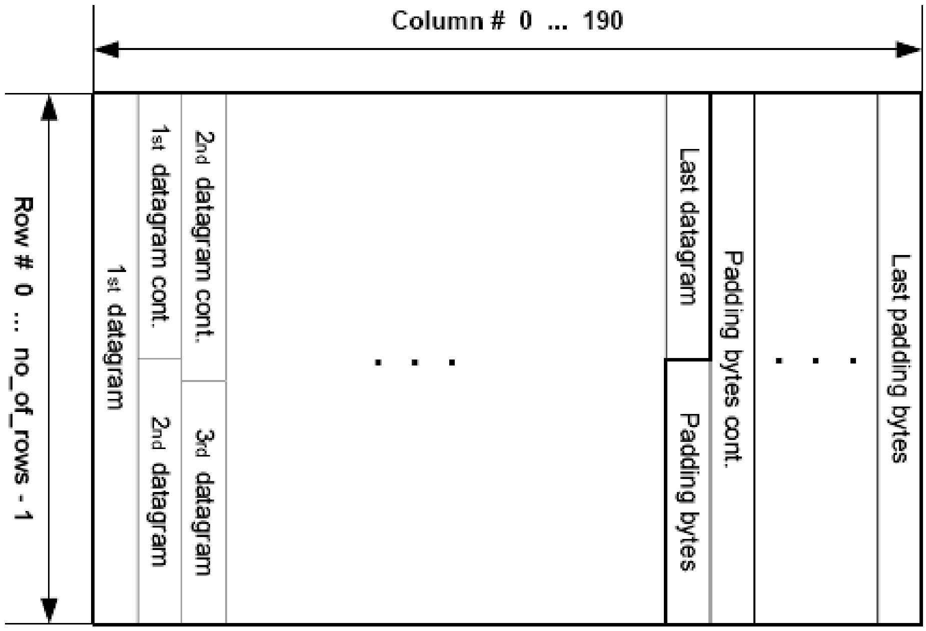

Figure 13: Layout of the Application data table.

MPE-FEC frame encoding is established by filling the Application data table column-wise with IP datagrams (see *Figure 13*). IP datagrams are introduced datagram-by-datagram starting with the first *byte* of the first datagram in the upper corner of the Application Data Table matrix and going downwards to the second column (see *Figure 14:*). When all datagrams are established, padding bytes complete the Application data table. Such padding *bytes* columns are used only for calculation of parity *bytes* and are not being transmitted.

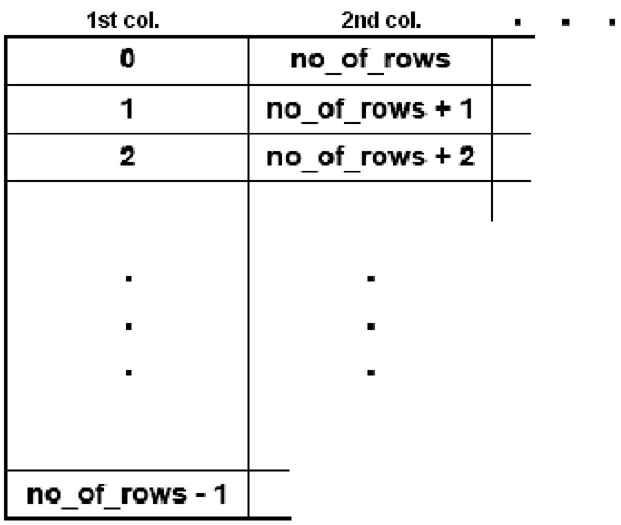

Figure 14: Addressing of byte positions in MPE-FEC data tables.

The Application Data Table is then encoded row-wise with a Reed-Solomon RS (255,191) to calculate the 64 parity *bytes* (FEC codewords) from the 191 *bytes* of data and possible padding (see *Figure 13*) which fills RS data table column-wise (see *Figure 15*) and resulting in MPE-FEC frames of 255 rows. Some of the rightmost columns of the RS data table may be discarded and hence not transmitted, to enable puncturing [5] (see *Figure 15*).

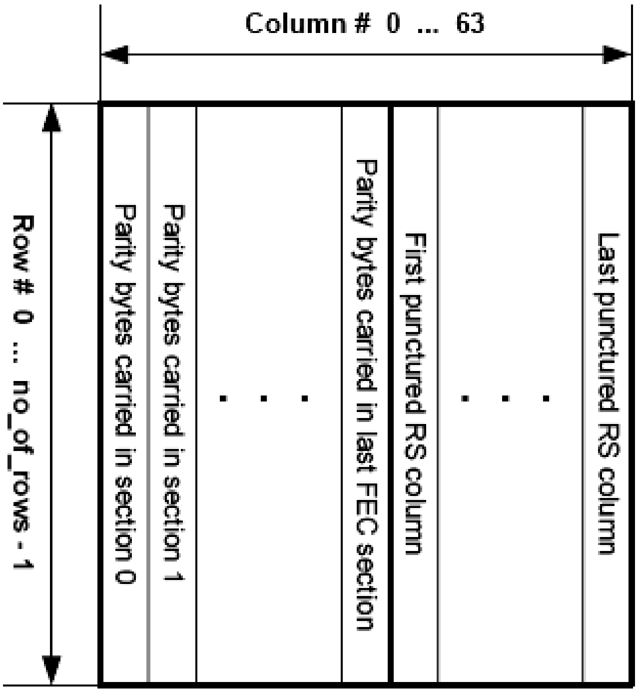

Figure 15: Layout of the RS data table.

After encoding, the IP datagrams are encapsulated in MPE sections (one IP datagram as payload) and the 64 parity columns are encapsulated in 64 MPE-FEC sections (one RS column as payload).

Encapsulation in sections (see *Figure 16*) means that the payload (IP datagram or MPE-FEC parity column) is preceded by a 12 *bytes* section header and followed by a 4 *byte* Cyclic Redundancy Check (CRC).

CRC can be used as a source of errors information for telling the link-layer FEC decoder about the integrity of IP-datagrams. Each section is protected with a CRC-32 code (see *Figure 16*) [6].

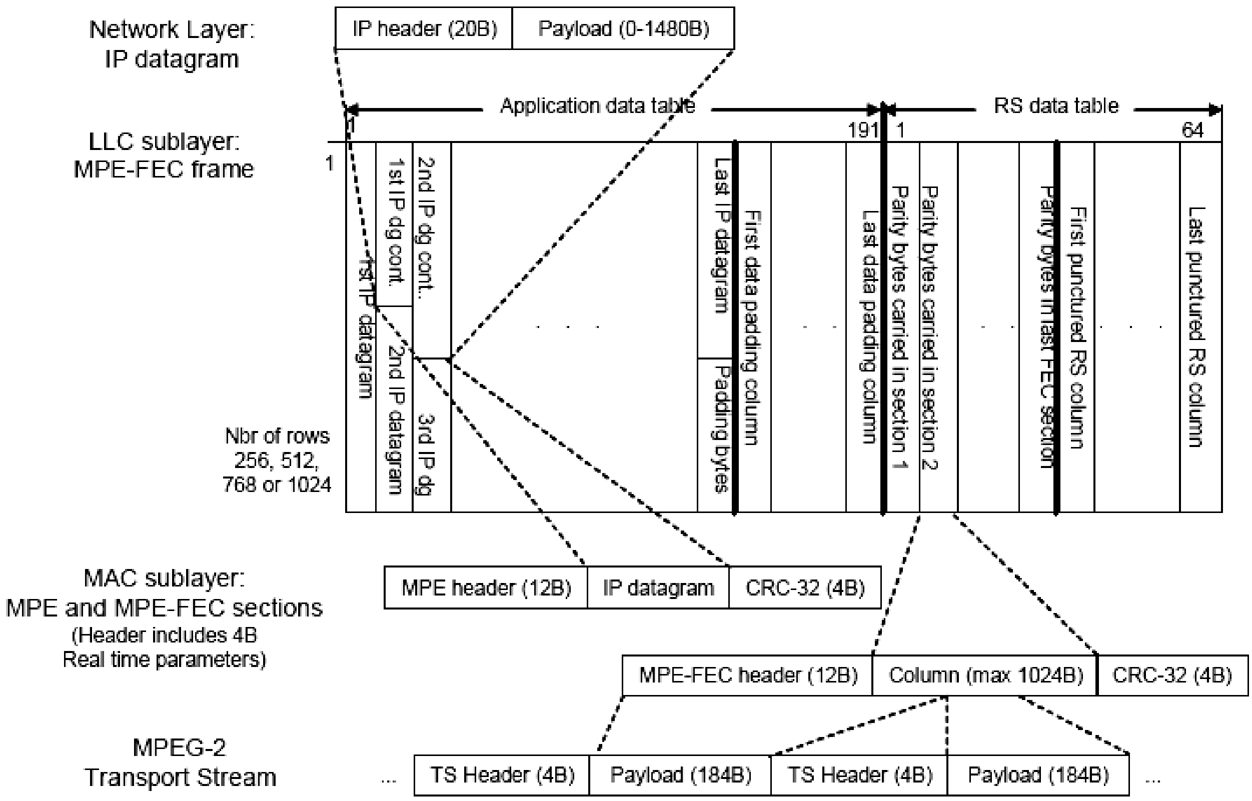

Figure 16: The layout of the MPE-FEC Frame.

The section header contains information regarding section length, MPE-FEC array address and time-slicing information. The MPE and MPE-FEC sections are inserted in the MPEG-2 transport stream. For this purpose, the sections are divided into 184 *bytes* fragments and transmitted as payload of Transport Stream (TS) packets. The 188 *bytes* TS packets are encoded with a [204, 188] RS code and a convolutional code, modulated with an OFDM modulator and broadcasted (DVB-T [2]).

At the receiver, MPE-FEC decoding can be started after the MPE-FEC Frame has been reconstructed. Using the time slicing parameters the receiver ensures that it is synchronised to the correct burst. At TS level, synchronizing to the service of interest is established by monitoring the Packet Identifier (PID), which is a 13 *bits* field in the 4 *bytes* TS packet header [7].

The decoding is suggested to be erasure correction based on reliability information provided by the CRC.

3.2 DVB Compatibility

As the DVB-H service IP datagrams are broadcasted using the traditional MPE encapsulation method this allows DVB-H services to share the MPEG-TS multiplex with traditional MPEG-2 based broadcast services. Therefore, any DVB receiver will be able to recover these IP data.

In case of dual transmission over DVB-T network [2], both DVB-T and DVB-H receivers will be supplied with the same signal, allowing DVB-T receivers to decode the whole services, while DVB-

H receivers will benefit of the DVB-H transmission features (additional MPE-FEC protection which is ignored by traditional DVB receivers).

Also, DVB-H capable receivers will be able to take care of the MPE section header to exploit the service time-sliced transmission (to reduce cleverly power consumption), while traditional DVB receivers will simply decode the MPE data contents.

In short, technical components provided to the DVB-H data link layer could be totally ignored by traditional DVB receivers while providing a benefit to DVB-H receivers. Accordingly, traditional DVB services and DVB-H services can share the same transport stream without any mutual inconvenience [8].

4 Simulation Results and Analysis

4.1. Physical and link layer parameters

One of the greatest challenges in DVB-H is in finding the best combination of system parameters (see some examples in *Table 6*). Different coding, interleaving and modulation makes a huge amount of parameter combinations and these have to be critically evaluated before building the networks. In *Table 6*, we describe four scenarios where the main difference amongst them is the symbol interleaver depth. In this deliverable, we only provide simulation results for Option1.

Parameters	***Options***	***Option 1***	***Option 2***	***Option 3***	***Option 4***
Modulation	QPSK, 16QAM, 64QAM	64QAM	64QAM	64QAM	64QAM
FFT-size	2k, 4k, 8k	2k	2k	4k	4k
In-depth interleaver	On/Off (only for 2k and 4k)	Off	On	Off	On
Guard Interval	1/4, 1/8, 1/16, 1/32	1/8	1/8	1/8	1/8
Convolutional code rate	1/2, 2/3, 3/4, 5/6, 7/8, 1(=no FEC)	3/4	3/4	3/4	3/4
N. of rows (MPE-FEC)	256, 512, 768, 1024 rows	512	512	512	512
MPE Burst Size	Max 1500 Bytes	512+16	512+16	512+16	512+16

Table 6: DVB-H parameters.

In terms of mobile radio channel, let us assume Profile A (P_m= 0, -7, -15, -22, -24, -19 dB; 0, 3, 8, 11, 13, 21 μs) from extended Cost 231 as mentioned in deliverable D2.1. The error trace files for other combinations of parameters will be generated and made freely available for the research community.

4.2. Results

As can be observed in *Figure 17* the BER decreases linearly in the dB domain as the SNR increases. The BER decreases dramatically after MPE-FEC. For SNR greater than 30 dB, the BER and the PER are equal to zero as shown in *Figure 18* and *Figure 19*. The vehicular speed also influences the performance significantly. We have focused our simulations to 60 and 140 km/h at a carrier frequency of 826 MHz (Channel 65) and 64-QAM. This corresponds to the worst conditions since the carrier frequency is very high and the sub-carriers are modulated by maximum number of levels. The results have not been crosschecked yet.

Any error traces files related to WiMAX, DVB-T/H and WLAN (see also deliverables D2.3 and D2.4) can be downloaded from SUIT webpage.

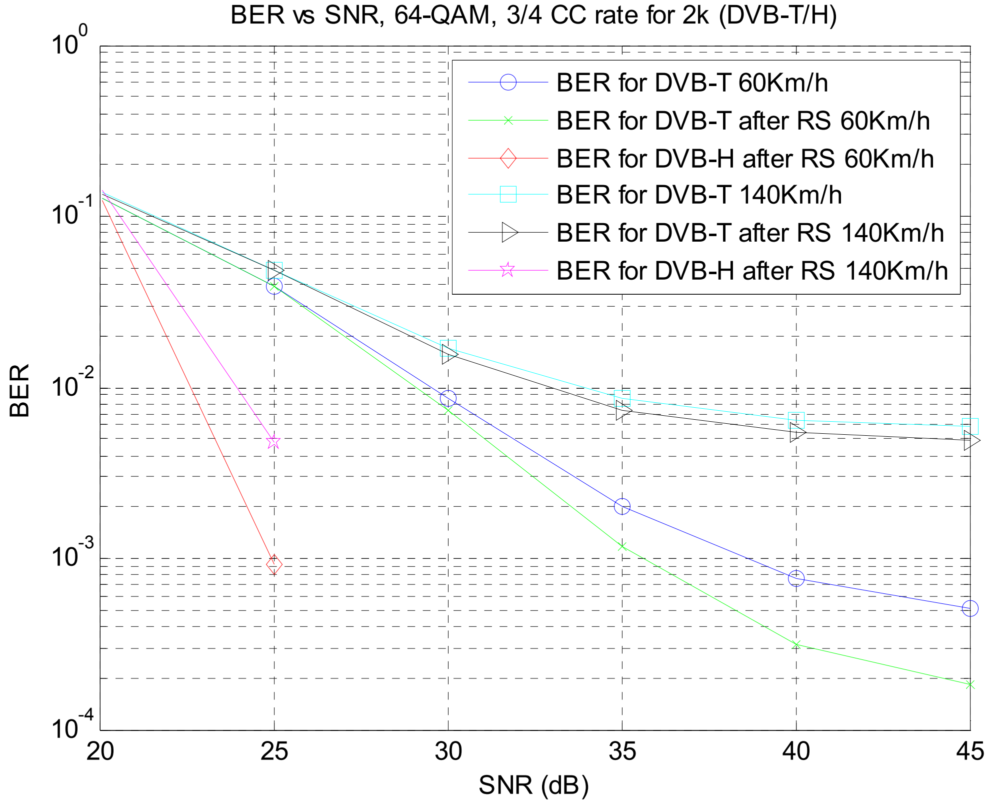

Figure 17: BER before and after RS and after MPE-FEC for 2k mode- native interleaving.

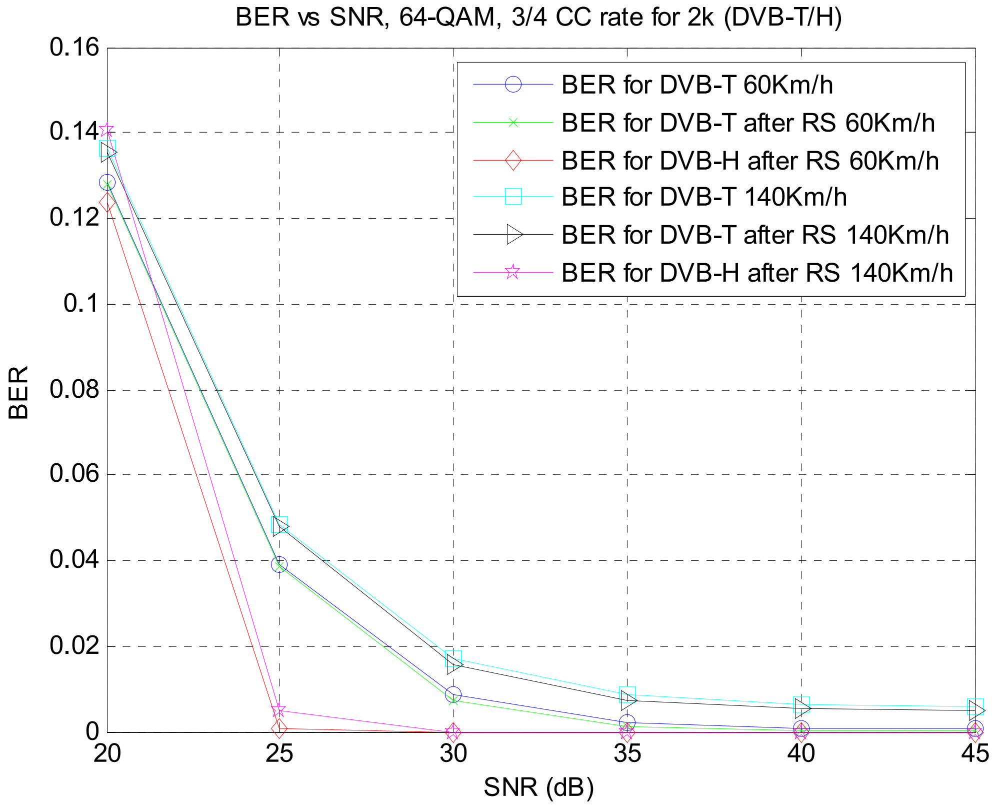

Figure 18: BER before and after RS and after MPE-FEC for 2k mode- native interleaving.

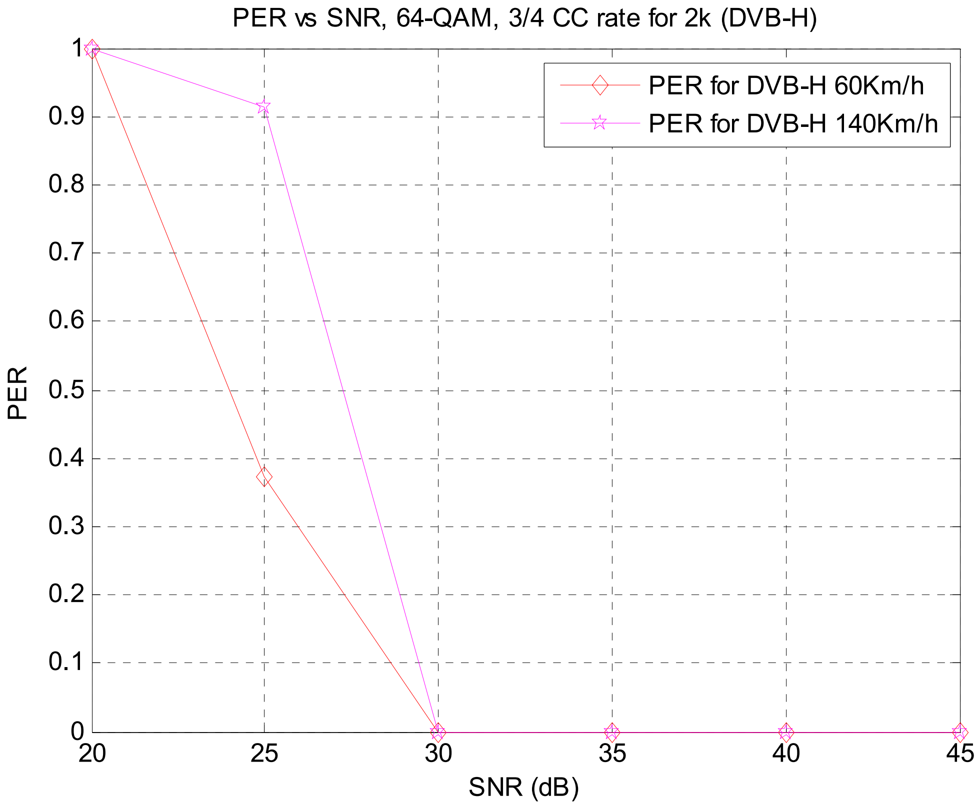

Figure 19: PER before after MPE-FEC for 2k mode- native interleaving.

The PER can be determined from the BER by using the formula,

$$PER=1-(1-BER)^{512}$$

5 Conclusions

This deliverable describes the DVB-T/H simulation models developed within the project. The first section of this deliverable provides an overview of the main objectives of this deliverable. In the second section, the DVB-T/H physical layer specifications are described where all modules are defined in the DVB-T/H standard. In the third section, the link layer of DVB-T/H is presented. From the results section, it can be observed that DVB-T/H is fairly robust to high vehicular speeds (Doppler spread) from the simulations carried out for 140 km/h. Note that, in our simulations, we have assumed an IP packet size of 512 bytes. However, other packet sizes are possible like 256, 768 and 1024. This is to allow flexibility on choice of packet size, the data throughput, and also to permit studies on efficient packetization schemes. The DVB-T/H error pattern will be used to develop optimal video parameters in WP3.

6 Acronyms

A/V	Audio/ Video or Audio Visual
ACI	Adjacent-Channel Interference
BER	Bit Error Rate
BST	Base station
CC	Convolutional Coding
C/N	Carrier-to-Noise Ratio
CINR	Carrier-to-Interference-and-Noise Ratio
CPE	Consumer Products Equipment
DHCP	Dynamic Host Configuration Protocol
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting - Handhelds
DVB-RCT	Digital Video Broadcasting - Return Channel Terrestrial
DVB-T	Digital Video Broadcasting –Terrestrial
ETSI	European Telecommunications Standards Institute
HDTV	High Definition Television
FEC	Forward Error Correction
FIFO	First In First Out
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IFFT	Inverse Fast Fourier Transformation
IPTV	Internet Protocol TV
ISI	Inter-Symbol Interference
IT	Instituto de Telecomunicações
LDPC	Low Density Parity Check
LLC	Logical Link Control
MAC	Media Access Control
MFN	Multi-Frequency Network
MHP	Multimedia Home Platform
MPE	Multi-Protocol Encapsulation
MPEG	Moving Pictures Expert Group
MSB	Most Significant Byte
NAT	Network Address Translation
NTSC	National Television Standards Committee
OFDM	Orthogonal Frequency Division Multiplexing

PAL	Phase Alternating Line
PER	Packet Error Rate
PID	Packed ID
PRBS	Pseudorandom Binary Sequence
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RS	Reed-Solomon
RSSI	Received Signal Strength Measurements
SECAM	*Sequentiel Couleur Avec Memoire* or Sequential Color with Memory
SFN	Single Frequency Network
S/N	Signal-to-Noise Ratio
SNR	Signal-to-Noise Ratio
TS	Transport Stream
UHF	Ultra High Frequency
VHF	Very High Frequency
VLAN	Virtual Local Area Network
WIFI	Wireless Fidelity
WIMAX	Wireless Local Area Network (in accordance with IEEE 802.16e)
WLAN	Wireless Local Area Network (in accordance with IEEE 802.11g)

7 References

[1] ETSI EN 302 304, v.1.1.1, *Digital Video Broadcasting: Transmission System for Handheld Terminals (DVB-H)*, ETSI standard, November 2004.

[2] ETSI EN 300 744, v.1.5.1, *Digital Video Broadcasting (DVB): Framing structure, channel coding and modulation for digital terrestrial television (DVB-T)*, ETSI standard, Jan 2004.

[3] C. H. Liew et al, *Fixed and Mobile Channel Models Identifications*, Deliverable D2.1-SUIT_64, Project SUIT, IST-4-028042, July 2006.

[4] ETSI EN 301 192, v.1.4.1, *Digital Video Broadcasting (DVB): DVB specification for data broadcasting (DVB-DATA)*, November 2004.

[5] ETSI TR 102 377, v.1.1.1, Digital Video Broadcasting: DVB-H Implementation Guidelines, 2005.

[6] Heidi Joki and Jussi Poikonen, *Analysis and Simulation of DVB-H Link Layer,* Turku Centre for Computer Science, Technical Report, n.º 695, June 2005.

[7] Mehdi Rezaei, Miska M. Hannuksela, Moncef Gabbouj, *Video Encoding and Splicing for tune-in time reduction in IP data casting (IPDC) over DVB-H*, IEEE ICME 2006.

[8] Gerard Faria, *DVB-H to deliver digital TV to Hand-Held Terminals*, BCA4088, France, 2004.