Simulations of PSI/SI Transmission in DVB-H Systems

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Abstract

The robustness of the transmission of application data in DVB-H systems has been investigated in several papers. However, the transmission of Program Specific Information/Service Information (PSI/SI) necessary for the service discovery within DVB-H is not that well examined. While the data carried inside MPE and MPE-FEC sections is protected at the link layer by MPE-FEC, the PSI/SI is not and its transmission relies solely on periodic retransmission. There is a question whether the transmission of the PSI/SI is practical in mobile environment as it is done presently. In this paper results of computer simulations on PSI/SI transmission in a mobile multipath channel are illustrated together with analysis of the results.

Keywords

Mobile TV, DVB-H, IP datacasting, signaling, PSI/SI

1. INTRODUCTION

DVB-H (Digital Video Broadcasting for Handheld terminals) is a data broadcasting standard [1] that enables delivery of various Internet Protocol (IP) based services to mobile receivers. The DVB-H standard, which is based on and is compatible with DVB-T (Digital Video Broadcasting - Terrestrial) [2], introduces solutions to the problems caused by the mobility of the handheld terminals receiving digital broadcast. A good overview of DVB-H systems can be found in [3].

PSI/SI (Program Specific Information/Service Information) [4][5][6] is an essential part of service discovery in DVB-H systems. The PSI/SI access time has a direct effect on the total latency in service access. From the end user point of view, the fast service access time is preferred and hence the PSI/SI access time should be minimized. In DVB-H the PSI/SI information is carried in MPEG-2 private table structures [4]. These structures are tables that are segmented into sections and carried inside transport stream (TS) packets. PSI/SI is transmitted with a certain retransmission interval to enable tapping into the network. The sections contain CRC (Cyclic Redundancy Check) information allowing the receiver to check the correctness of the received sections. If the receiver detects that some sections carrying one subtable during one transmission are in error it has to wait for the next transmission to receive the missing sections. Although the application data is protected at the link layer by the MPE-FEC to combat the effects of mobility, the transmission of the PSI/SI information is left uncoded. Therefore a question arises, whether the transmission of the PSI/SI information in its present form is robust enough for mobile receivers. The issue of robustness is briefly touched upon in [7] and further studied in [8], but needs still further research.

In this document, simulation results of PSI/SI transmission using three different decoding methods with mobile multipath channel model TU6 [9] are presented. First the simulated network configurations are discussed. Then, in section 2.1, the performance comparison of the decoding methods is done with uniform error distribution. The simulation results in TU6 channel model are presented in section 2.2. Here the effects of repetition interval and section sizes for different configurations are presented. Further, also network capacity issues considered in [8] are analyzed in mobile channel in section 3. Section 4 presents the results of simulations on field measurements. Finally, in section 5 concluding remarks are given.

2. SIMULATIONS

The simulations cover the transmission and reception of the PSI/SI. The physical channel model between the transmitter and receiver is commonly used TU6 [9] mobile multipath channel model. Three different network configurations were considered. These configurations are named “Low Cost” (LC), “Typical” (T) and “Maximum Mobile” (MM) and their network parameters are given in Table 1. These configurations are similar to the ones considered in [8] except for the different Guard Interval (1/4 instead of 1/8 of pure OFDM symbol duration).

Table 1: Simulated Configurations

Configuration	LC	T	MM
Mode	8k	8k	8k
Constellation	QPSK	16-QAM	16-QAM
Conv. Coderate	1/2	1/2	2/3
Guard Interval	1/4	1/4	1/4
Bandwidth	8 MHz	8 MHz	8 MHz

2.1 Decoding Methods

The simulator simulates three different decoding methods for the PSI/SI tables. The first one we call “intelligent” decoder. It is capable of keeping all correctly received sections in memory until all the sections are correctly received and the table can be reconstructed. The second decoder is “correct order” that requires the correct sections to be received in correct order. The third decoder is the least intelligent and called “all ok at once”. It requires that all sections of a table must be received correctly during one transmission for correct reception. The most important output of the simulations is the percentage of users that have received the table correctly with certain number of retransmissions (from now on this is called coverage). The performance difference of the decoders for a table of size 8192B (Byte) transmitted in 512B sections is illustrated in Figure 1 for TS PER (TS Packet Error Rate) 15% and uniform error distribution. It is seen that to obtain user coverage of for example 95%, eight transmissions are needed for “intelligent” decoder. For “correct order” decoder this number is 20 and for “all ok at once” it is rather large. It is easy to see and deduce that in any situation the intelligent decoder is the best of these three and its use is therefore recommendable. This is the reason why our main focus in the following sections is on the intelligent decoder, unless otherwise stated.

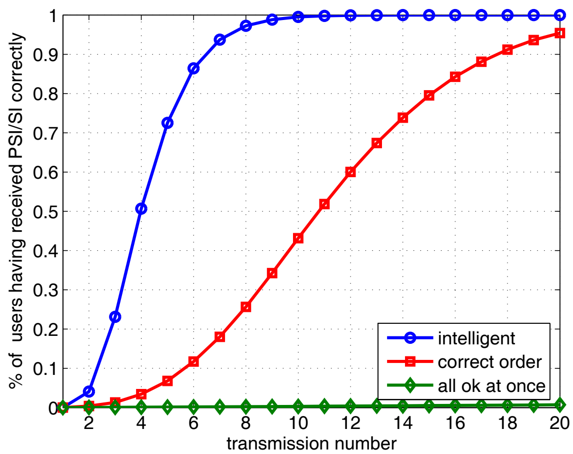

Figure 1: Performance of different decoding methods for PSI/SI in the receiver

2.2 Mobile channel simulations

The TU6 simulations were performed with recorded TS packet error traces that are receiver dependent. To obtain the error traces the transmitted signal has been generated, modulated and ran through a channel simulator with TU6 channel profile. Then the signal was received by a DVB-T receiver supporting mobile reception (8-tap channel estimation in time direction) and the transport error indicators (TEI) were collected. Transport error indicators directly inform us whether each TS packet was decoded correctly by the physical layer RS (Reed-Solomon) decoder or not, i.e. are there errors left in the packet. With TU6 error traces the effect of the motion of the receiver on the PSI/SI transmission can be studied. Traces were available for Doppler frequencies $f_D =$ 2 Hz, 10 Hz, 30 Hz and 80 Hz and C/N values corresponding to TS PER from around 40 % to nearly error free transmission with 1 dB resolution. Simulated table and section sizes together with repetition intervals for all three network configurations and decoding schemes are given in Table 2. The simulation matrix is rather large to reveal the behaviour of the transmission in this environment. 10000 users were considered to be enough for each simulation.

Table 2: Simulated Parameters

Table B	Section lengths (B)	Rep. Intervals (s)
16384	64, 128, 256, 512, 1024, 2048, 4096	1, 5, 10, 15, 30
8192	64, 128, 256, 512, 1024, 2048, 4096	1, 5, 10, 15, 30
4096	64, 128, 256, 512, 1024, 2048, 4096	1, 5, 10, 15, 30
1024	64, 128, 256, 512, 1024	1, 5, 10, 15, 30
768	64, 128, 256, 512	1, 5, 10, 15, 30
512	64, 128, 256, 512	1, 5, 10, 15, 30
256	64, 128, 256	1, 5, 10, 15, 30
16	8, 16	.025, .05, .075, .1
8	8	.025, .05, .075, .1

2.2.1 The effect of repetition interval on C/N requirement

The repetition interval has only a slight effect on the C/N requirement to obtain certain reception coverage with different numbers of transmissions. The percentage of receivers receiving a table of size 8192B with 512B sections correctly with three transmissions is presented in Figure 2 for typical (T) configuration and Doppler frequency $f_D = 10$ Hz. It is evident that the curves differ very little from each other. This means that having the same channel conditions, the repetition interval has almost no effect on the reception coverage percentage. The network capacity required by the transmission and the time for the receiver to obtain the table, on the other hand, are directly affected by the repetition interval. Sending tables more frequently naturally increases the used network capacity and shortens the time receiver has to wait before acquiring all the sections correctly. More on this section 3.

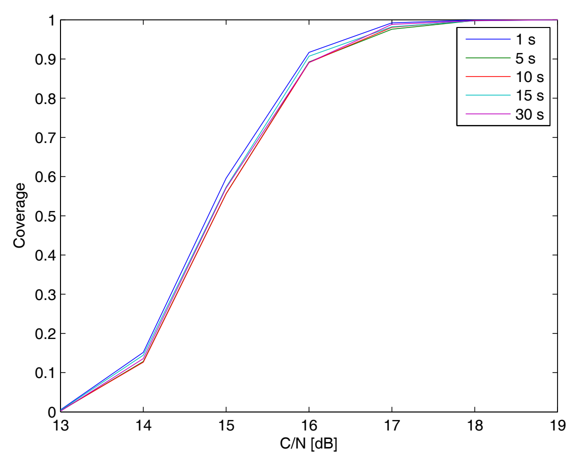

Figure 2: The effect of repetition interval for 8192B table transmitted with 512B sections (T)

2.2.2 The effect of section size

Let us begin by considering two Doppler frequencies $f_D = 10$ Hz and 80 Hz with typical (T) network configuration as an example. Consider that intelligent decoder is used and 95% user coverage is necessary. The curves for transmission of the table with sections of sizes 64B, 1024B and 4096B are shown in Figure 3.

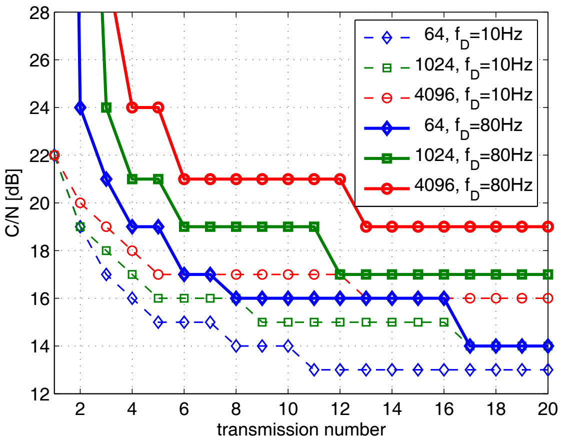

Figure 3: The effect of section length to obtain 95% coverage for 16384Bb table (T)

From Figure 3 it can be observed that using 64B sections instead of 4096B ones gives us approximately 2-3 dB gain in TU6 channel with $f_D = 10$ Hz in T network configuration. For $f_D = 80$ Hz the gain is even 4 dB. Similar order with different gains is observed also with other network configurations. The effect of total table size is not as remarkable as the effect of the section length, but naturally when transmitted with similar length sections a smaller table consisting of fewer sections can be received correctly more quickly.

Let us further investigate the effect of Doppler frequency on the transmission of PSI/SI as compared to the transmission of the data protected by MPE-FEC with 512 row frame and code rate 3/4. Comparison to the datapath is informative, since at least when the datapath is operating above some certain error criteria, the PSI/SI transmission should work as well to enable service discovery. For all PSI/SI results here the total table size used is 16384B and it is required to obtain the coverage using 6 transmissions with 5s repetition interval. This could be a realistic size for the largest table INT (IP/MAC Notification Table) used in the DVB-H systems being in the same time the most error prone. The maximum repetition interval for INT is 30s [10]. Let us decide that 95 % user coverage should be obtained during this time. So, if repetition interval of 5s is used, six transmissions should be enough to obtain the wanted coverage. If the network is planned according to the MFER=5% (MPE-FEC Frame Error Ratio) criteria, the curves lying above (at higher C/N values) the corresponding MFER curve cannot be considered viable.

For example, in Figure 4 for LC configuration correct order and all-ok decoders require higher C/N to obtain 95 % user coverage than is designed and only intelligent decoder is a working option in this example. This further justifies the fact that intelligent decoder is the best of the three decoding methods presented here. Yet again, the results are valid for the receiver used in the generation of the TS error traces. The performance of other receiver implementations at different Doppler frequencies can differ from the receiver used here, but most likely the general behavior is of the same kind. For T configuration the effect of section size is presented in Figure 5.

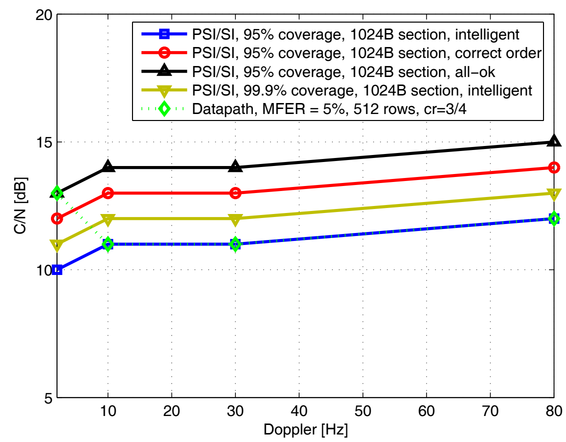

Figure 4: Comparison of decoding methods and required coverage percentage (LC)

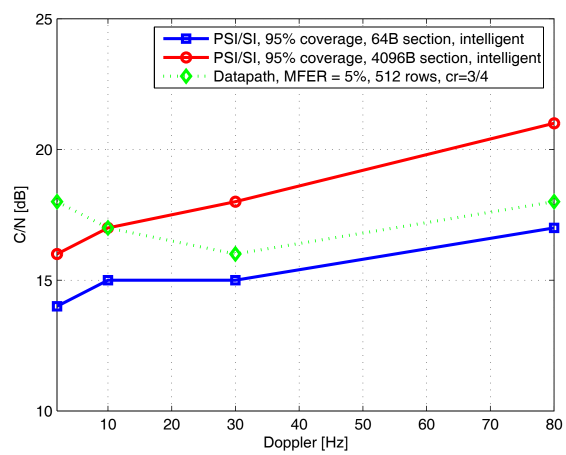

Figure 5: Comparison of different section sizes (T)

The gain of using the smallest sections instead of the largest ones is observed to be approximately 3 dB in T network configuration. The values for Doppler frequencies $f_D = 10$ Hz and 80 Hz can also be seen in Figure 3. With the 64 byte sections it can also be observed that obtaining the required coverage is possible with smaller C/N value than for obtaining MFER=5% in the datapath, so the PSI/SI transmission is more robust than the datapath in this case and it can be considered to be working. The curves for section sizes between 64B and 4096B lie between the curves for these section sizes. It must be noted that the exact shape of the Doppler curves could not be obtained, since error traces only for $f_D = 2$, 10, 30 and 80 Hz were available.

In reality using shorter sections with some subtables increases the total size of the subtable (this situation is considered in section 3). In these simulations hypothetic table and section sizes given in Table 2 were used meaning that the variation in section size doesn't introduce any changes in the total table size. This was done to obtain more general insight into the behavior of the PSI/SI transmission in mobile multipath channel. It is evident from the simulations that to obtain similar coverage for large tables with longest sections as with the shortest ones, several dB higher C/N is required. For the small tables (8B and 16B) there is no visible difference between the different section sizes. Of the four measured Doppler frequencies $f_D = 80$ Hz is the most challenging, i.e. highest C/N is required to obtain 95% coverage and respectively $f_D = 2$ Hz is the least demanding.

3. NETWORK CAPACITY CONSIDERATIONS

If the effect of varying section size on the total table size is taken into account (as is done in [8]), the shortest sections are not necessarily the best from the reserved network capacity point of view. The increase in total table size with decreasing section size is caused by the additional overhead induced by the increased number of sections. Let us consider here the T configuration. The necessary numbers of required transmissions to obtain the 95% coverage in T network configuration for the PSI/SI at the C/N where the MFER=5%, are shown in Table 3. For different section lengths the worst case of the Doppler frequencies needs to be considered (marked with bold face font in Table 3), i.e. the largest amount of transmissions is the limiting factor for each section size, since while planning the network worst case velocities of the receivers should be taken into account. For example, INT with 512B sections needs to be transmitted 5 times to obtain the required coverage.

The required network capacity for the transmission of the tables can be calculated if we assume that it is necessary to reach the coverage of 95 % of users within the maximal repetition intervals given in Table 4 (collected from the standards) at any Doppler frequency. The acronyms for the tables are: INT (IP/MAC Notification Table), NIT (Network Information Table), PAT (Program Association Table), PMT (Program Map Table) and TDT (Time and Date Table). These form the main PSI/SI necessary in DVB-H IP-datacasting [7]. Figure 6 presents the reserved network capacity as a function of the section length for INT and NIT. From the network capacity point of view, the optimal section length for INT is 512B and for NIT it is 756B.

Table 3: Necessary number of transmission to reach 95% coverage at C/N corresponding to MFER = 5% (T) for different section lengths

Table				
INT	f_D=2Hz	f_D=10Hz	f_D=30Hz	f_D=80Hz
203B	2	3	**5**	4
512B	2	3	**5**	4
1024B	2	3	**6**	4
2048B	2	4	**9**	6
4096B	2	4	**19**	10
NIT				
96B	1	2	**3**	2
128B	1	2	**3**	2
256B	1	2	**3**	2
512B	1	2	**3**	2
756B	1	2	**3**	2
PAT				
16B	**1**	**1**	**1**	**1**
PMT				
394B	1	**2**	**2**	**2**
TDT				
8B	**1**	**1**	**1**	**1**

Table 4: Repetition interval ranges [5],[7],[10]

Table	Min	Max
NIT	25 ms	10 s
PAT	25 ms	100 ms
PMT	25 ms	100 ms
INT	25 ms	30 s
TDT	25 ms	30 s

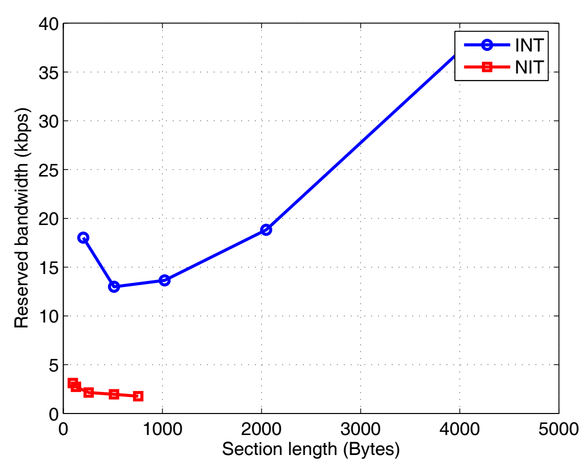

Figure 6: Network capacities reserved by INT and NIT

The overall network capacity reserved by the five tables using these optimal section sizes is calculated to be:

$$\frac{9971\times 8}{(30s/5)}+\frac{756\times 8}{(10s/3)}+\frac{394\times 8}{(0.1s/2)}+\frac{16\times 8}{0.1s}+\frac{8\times 8}{30s}\approx 77.6\ \text{kbps},$$

that is less than 1 % of the total network capacity of 9.95 Mbps in T network configuration. Most of this network capacity is reserved by PMT that requires 61.6 kbps due to the short repetition interval. The total sizes for the tables using sections of these sizes are: INT 9971B, NIT 756B, PMT 394B, PAT 16B and TDT 8B.

4. SIMULATIONS BASED ON FIELD MEASUREMENTS

The field measurements were performed in the city of Turku on a non-hierarchical DVB-H signal with the center frequency 498 MHz in two-transmitter SFN (Single Frequency Network), with the transmitters located approximately 4 km from each other. Physical layer parameters measured were 16-QAM modulation with convolutional code rate 1/2 and the 8k OFDM mode. The guard interval of 1/4 of the OFDM symbol duration was used. In the measurements four use cases were considered: Pedestrian outdoor (3 km/h), Pedestrian indoor (3 km/h), Vehicular urban (30 km/h) and Motorway (100 km/h). The block diagram for the measurement setup is shown in Figure 7.

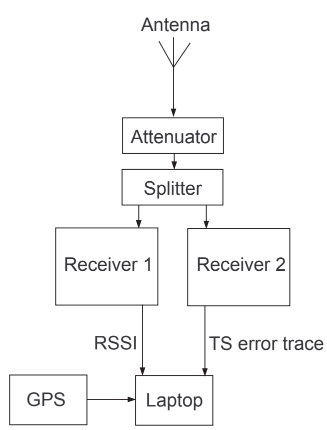

Figure 7: Measurement setup

In the pedestrian use cases the measurement system was carried in a backpack with the antenna outside the pack and in the vehicular measurements the antenna was located on the rooftop of the car. The indoor measurements were performed in a shopping center with a variation of open squares with glass roofs and narrow passageways. Measurements in both pedestrian use cases were performed close to the transmitter in the city center; the vehicular urban use case was measured between the two transmitters and the motorway use case in the coverage area of the further transmitter.

The results of simulations on PSI/SI transmission in the four usage scenarios are presented in Figure 8. The INT table of total size 7683B in T network configuration with 4096B sections was simulated. Attenuator was used to obtain such a signal level that errors do occur in the reception. During one measurement the attenuation was kept constant. The MFER values for the measurements used in the simulations are: Pedestrian indoor = 53%, Pedestrian outdoor = 10%, Vehicular urban = 5% and Motorway = 35%. Important notion of the figures is that even when the reception of the application data can be considered to be impossible, for example in the pedestrian indoor case with MFER=53%, 95% coverage for the PSI/SI can be reached already with 6 transmissions. It is clear that the distribution of TS errors is different in the use cases and, for example, in pedestrian indoor measurements there are error bursts of duration reaching up to several seconds and sometimes the reception can be perfectly clear resulting in quite good overall PSI/SI transmission. As a contradictory example, in the motorway measurements TS errors are rather evenly distributed and the performance of PSI/SI transmission is quite poor. The curves in the figure are not directly comparable to one another since there are fluctuations in signal strength, but it can be verified that PSI/SI transmission actually works in real mobile environment also.

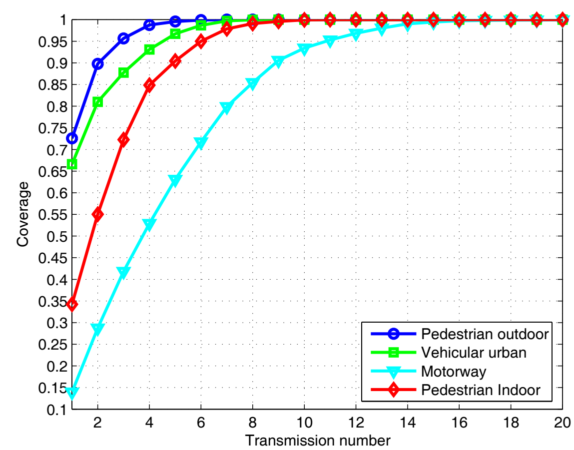

Figure 8: PSI/SI transmission in real environment

5. CONCLUSIONS

In this paper simulations on the performance of PSI/SI transmission in DVB-H systems in a mobile environment were presented. The effects of repetition interval, section size and decoding method on different channel conditions and network configurations were presented. Also, a comparison to the theoretical calculations presented in [8] was made on the side of network capacity usage optimization.

First of all, intelligent decoder should be used due to its superior performance over the other two decoding methods. Based on the simulation results it is also advisable to use as short sections in the transmission of PSI/SI as possible. If the transmission of PSI/SI is optimized with respect to the used network capacity and the impact of varying section size on the total subtable size is taken into account, the smallest section size is not necessarily the best option, but some optimal section size can be found. It seems according to the simulations with TU6 channel and field measurements that the PSI/SI transmission as it is organized presently is able to provide robust enough transmission presuming that some effort is put on the selection of the PSI/SI transmission parameters.

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