DVB-H Broadcast Network Design for indoor reception of DVB-H in Flanders

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Abstract
The digital broadcasting standard DVB-H (Digital Video Broadcasting - Handheld) enables a high data rate broadcast access for hand-held terminals. In the Flemish DVB-H trial, the network is designed for portable coverage in houses. The objective of this paper is to determine the required number of base stations (BS) for good indoor reception in Flanders (13,522 km^2) using a coverage model based on the measured performance of the trial network.

Keywords
DVB-H, indoor reception, number of base stations, coverage, Field trial, propagation, Digital Video Broadcasting - Handheld.

INTRODUCTION
In this paper we determine the number of base stations (BS) for DVB-H coverage in Flanders and Brussels. We will make use of the existing models [5] and coverage models developed using propagation measurements in the DVB-H network in Ghent [1]. Different categories of base stations are defined and different scenarios are proposed. The number of base stations for "good indoor reception" will then be determined for Flanders. Finally, the number of base stations as a function of the C/N ratio (carrier-to-noise ratio) is determined and a formula for this relationship is proposed.

METHOD

Selected parameters of base stations
We consider in this paper channel 37, which corresponds to 602 MHz (band V). This channel is used for testing in Ghent, Belgium. Furthermore, we will consider a channel width BW of 8 MHz. The required number of BS will be calculated for good indoor coverage for a throughput of about 10 Mbps [1]. This throughput is also used for the trial in Ghent, as described in [1]. The following settings were used: 4K mode, a guard interval of 1/8, modulation scheme 16-QAM 1/2, and MPE-FEC coding rate of 7/8. The resulting bit rate is then 9.68 Mbps. The "Multi Protocol Encapsulation –- Forward Error Correction" (MPE-FEC) interleaves the data and adds a Reed-Solomon Code in order to make the DVB-H signal more robust (in contrast to the DVB-T signal). For the estimation of the MPE-FEC gain, the data of [1] – [4], [7] is used for portable reception. An MPE-FEC gain of 3.0 dB was considered for portable and mobile reception [1], [7].
The network dimensioning has been executed for these settings.

Receiver
For the network dimensioning we consider the reference receiver Rx defined in [2]. Different reception classes have been adopted: only class B will be considered here. Class B is defined as hand-held portable indoor reception, 1.5 m above floor level in rooms at very low or no speed.
For planning purposes, a receiver gain G_r of -4.86 dBi can be used for Band V according to ETSI [2] (antenna in a small hand-held terminal). The minimum signal input level to the receiver is determined by the required C/N ratio. In [2], [6] C/N ratios are defined and the receiver noise figure (F) has been chosen as 6 dB for the frequency bands IV to V (reference receiver). For 16-QAM 1/2 the following parameters are defined according to ETSI TR 102 377 [2] for portable reception (BW = 8 MHz, band V, static Rayleigh channel, PER = Packet Error Rate = 10^{-4} [6]): C/N = 11.2 dB, Rx sensitivity of -88.0 dBm, and equivalent minimum receiver field strength E_{min} of 49.7 dBμV/m.

Area to be covered
The surface of Flanders with an area of 13,522 km^2 has to be covered. There are 13 cities in Flanders, namely 2 larger cities Antwerpen and Ghent and 11 regional cities: Aalst, Brugge, Genk, Hasselt, Kortrijk, Leuven, Mechelen, Oostende, Roeselare, St-Niklaas, Turnhout. The surface of these cities is 668.49 km^2. Also coverage for Brussels is necessary. The surface of this area (Brussels Hoofdstedelijk Gewest or BHG) is 162 km^2. The coverage will be calculated for 100 % of the population.

Categories
Three categories of base stations are defined:

- Category 1: low towers / low power, the height of the base station h_{BS} = 35 m, ERP = Equivalent Radiated Power = 2 kW
- Category 2: medium towers / medium power, h_{BS} = 60 m, ERP = 5 kW

- Category 3: high towers / high power, h_{BS} = 150 m, ERP = 20 kW

Using these categories, different scenarios for DVB-H coverage in Flanders will be defined. For all investigated scenarios, the network is first developed for rural coverage for Flanders. Additionally suburban coverage for the 13 cities and Brussels is provided.

Scenarios

Using these categories, five different scenarios are proposed: three scenarios with 100 % of the BS from one category, a realistic scenario based on the available antenna sites of the public broadcaster VRT (Flemish Radio and Television Network), supplemented by low power stations, and a scenario assuming building additional medium power infrastructure. For all investigated scenarios, the network is first developed for rural coverage. Additionally, suburban/urban coverage for the 13 cities and Brussels is provided.

Scenario 1

For scenario 1, Flanders and Brussels are covered for 100 % using base stations of category 1 (height h_{BS} = 35 m and ERP = 2 kW). Fig. 1 shows this scenario.

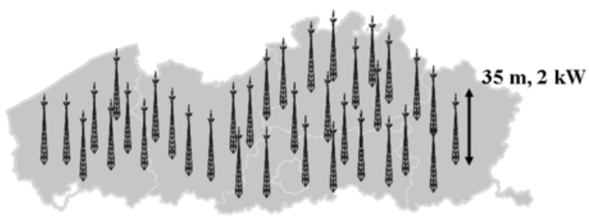

Figure 1. Coverage of Flanders using scenario 1.

Scenario 2

For scenario 2, Flanders and Brussels are covered for 100 % using base stations of category 2 (height h_{BS} = 60 m and ERP = 5 kW). Fig. 2 shows this scenario.

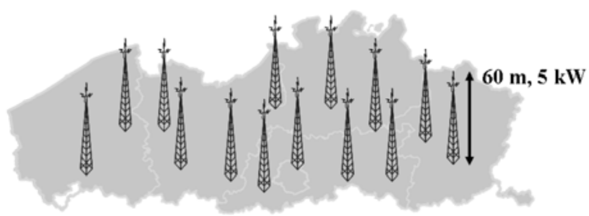

Figure 2. Coverage of Flanders using scenario 2.

Scenario 3

For scenario 3, Flanders and Brussels are covered for 100 % using base stations of category 3 (height h_{BS} = 150 m and ERP = 20 kW). Fig. 3 shows this scenario.

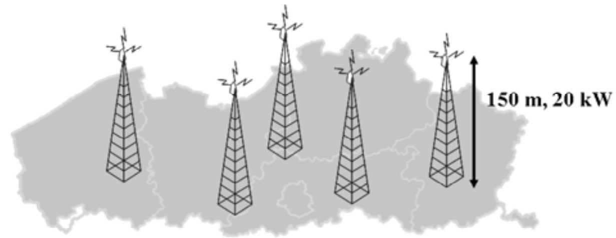

Figure 3. Coverage of Flanders using scenario 3.

Scenario 4

Scenario 4, is based upon available antenna sites of VRT in Flanders. Scenario 4 uses existing medium and high infrastructure ($h_{BS} \geq 60$ m). In Table 1, we assume 15 BS of category 2 and 5 BS of category 3 for rural coverage. Furthermore, we assume 5 BS of category 2 and 1 BS of category 3 in the regional cities. Finally, for Brussels there is 1 BS of category 3. The remaining number of BS of category 1 required for the coverage (indicated by "?" in Table 1) has then to be calculated (see further in this paper).

Table 1. Assumed number of base stations of category 2 and 3 for scenario 4.

category	Flanders rural	cities suburban	Brussels suburban
1	?	?	?
2	15	5	0
3	5	1	1

Scenario 5

The realistic scenario 5 assumes building additional medium infrastructure ($h_{BS} \geq 60$ m). In Table 2, we assume 50 BS of category 2 and 5 BS of category 3 for rural coverage. Furthermore, we assume 13 BS of category 2 (1 for every regional city) and 1 BS of category 3 in the regional cities. Finally, for Brussels there is 1 BS of category 3. The remaining number of BS of category 1 required for the coverage (indicated by "?" in Table 2) has then to be calculated (see further in this paper).

Table 2. Assumed number of base stations of category 2 and 3 for scenario 5.

category	Flanders rural	cities suburban	Brussels suburban
1	?	?	?
2	50	13	0
3	5	1	1

CALCULATION OF NUMBER OF BASE STATIONS

Models

To calculate the range of the system, path loss models are needed. The path loss (PL) between a pair of antennas is the ratio of the transmitted power to the received power. The path loss is modeled according to a lognormal shadowing model in [1]. The median path loss is modeled as:

$$PL = P_0 + 10\ n \cdot \log(d/d_0) + \chi \qquad (1)$$

where d is the distance between BS and Rx in m, d_0 is a reference distance in m, and n is the path-loss exponent. d_0 was chosen 100 m here. Furthermore, χ is the shadowing fading variation and has a standard deviation σ. To calculate the range of BS of category 2, the model of [1] – this will be noted as the Ghent model - will be used for suburban coverage (P_0 = 86.8 dB, n = 2.34, and σ = 6.18). The rural coverage will be calculated using the rural ITU-R P.1546 model [5]. The coverage of BS of categories 1 and 3 will also be calculated using the ITU-R P.1546 model [5].

The range of a single BS can then be calculated for the reference receiver of [2], [3]. The ranges R are summarized (together with the used models) in Table 3 for reception class B.

Table 3. Range of base station for different categories.

category	terrain	model	range R [km]
1	rural	ITU	2.45
	suburban	ITU	1.65
2	rural	ITU	4.15
	suburban	Ghent model	3.35
3	rural	ITU	10.20
	suburban	ITU	7.25

The covered area is assumed to be a circle or a hexagon (21 % less coverage). Using hexagons, empty spaces are avoided. The covered area for a BS is calculated for a circle as follows:

$$\text{Covered area}_{1BS} = \pi \cdot R^2 \qquad (2)$$

The covered area for a hexagon is calculated as follows:

$$\text{Covered area}_{1BS} = (3/2)\cdot\sqrt{3}\cdot R^2 \qquad (3)$$

The number of base stations #BS for a certain area with surface S is then:

$$\#BS = S / \text{Covered area}_{1BS} \qquad (4)$$

Results for different scenarios

The number of base stations obtained for *indoor* reception for scenarios 1 - 5 are shown in Table 4. For the suburban coverage in 13 cities, a minimum of 13 base station antennas is assumed when the #BS obtained from the calculations is smaller than 13 (e.g., for scenario 3). For scenario 1 (100 % category 1), the largest number of BS is of course obtained. The number of BS is much higher for hexagons compared to circles due to the less covered area of a single BS. From Table 4, it can be concluded that a large number of BS is required for the realistic scenario 4 (653 for circles) and scenario 5 (563 for circles). The #BS for scenario 5 is lower than for scenario 4 because in scenario 5 additional medium infrastructure would be built.

Table 4. #BS for different scenarios.

	#BS	
scenario	circle	hexagon
1	816	986
2	274	332
3	47	65
4	653	823
5	563	733

NUMBER OF BS VERSUS C/N

In this section the number of BS required for indoor DVB-H coverage in Flanders as a function of the C/N is determined. A high number of calculations was performed to obtain the #BS for C/N values from 5 to 20 dB. Up to now the reference receiver with C/N = 11.2 dB for class B was considered.

We consider the following settings and parameters:

- Class B
- 16 QAM 1/2, MPE-FEC 7/8
- Guard interval 1/8
- MPE-gain = 3.0 dB [1], [4], [7]
- Coverage for Flanders and Brussels
- C/N: varied from 5 – 20 dB

As an example, Fig. 4 shows the required number of base stations as a function of the C/N for scenario 2 using circles and hexagons. This figure shows that the number of BS and thus the costs are very sensitive to the C/N value. The dependence is exponentially: for a C/N of 13.8 dB for class B reception (value of a realistic handheld), 395 BS for scenario 2 for circles are needed (compared to 274 for the reference receiver with C/N = 11.2 dB).

Therefore, we modeled the number of base stations for the different scenarios as follows:

$$\#BS = a \cdot e^{b \cdot C/N} + c \qquad (5)$$

Where a, b, and c are the parameters of the model. Parameter c is of course zero for scenarios 1 to 3, as no constant number of existing or additional medium and high infrastructure is assumed. Fig. 4 shows the results of the fits for scenario 2. For the different scenarios, the average deviation between the model and the calculations is smaller than 2.5 %. Using this formula and the C/N of a terminal, one can make an estimate for the required number of BS for coverage in Flanders.

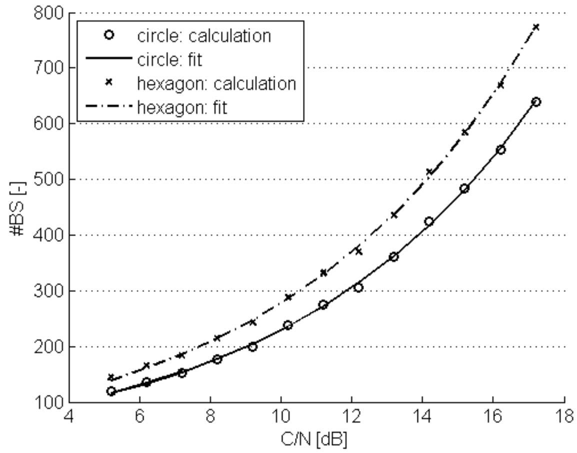

Figure 4. Coverage Calculated and fitted number of BS as a function of the C/N for scenario 2.

Table 5 shows the values for the parameters a, b, and c. Using these parameters, the required number of BS for the different scenarios can easily be calculated.

Table 5. Values of parameters a, b, and c to calculate #BS in Flanders for different scenarios.

scenario	area	a	b	c
1	circle	150.62	0.1508	0
	hexagon	181.71	0.1510	0
2	circle	55.09	0.1426	0
	hexagon	66.52	0.1427	0
3	circle	10.73	0.1335	0
	hexagon	12.85	0.1339	0
4	circle	78.13	0.1841	27
	hexagon	106.25	0.1781	27
5	circle	44.08	0.2136	70
	hexagon	67.60	0.2014	70

CONCLUSIONS

We have calculated the number of base stations required for good indoor DVB-H coverage in Flanders. Three different categories of base stations have been defined and five different scenarios have been proposed. Technical trial results are used to obtain realistic coverage models. We considered as parameter settings: 4K mode, 16-QAM 1/2, guard interval 1/8 and MPE-FEC coding rate of 7/8. This scheme results in a bit rate of 9.68 Mbps. For e.g., scenario 2, 274 base stations are necessary to obtain good coverage in Flanders. The number of base stations (and thus the cost) is very sensitive to the C/N value. This dependence has been modeled as an exponential function.

ACKNOWLEDGMENTS

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REFERENCES

[1] D. Plets, W. Joseph, L. Martens, E. Deventer, and H. Gauderis, “Evaluation and Validation of the Performance of a DVB-H Network”, 2007 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, Orlando, Florida, USA, March 28 – 29, 2007.

[2] ETSI, TR 102 377 v1.1.1, “Digital Video Broadcasting (DVB); DVB-H Implementation Guidelines,” Feb. 2005.

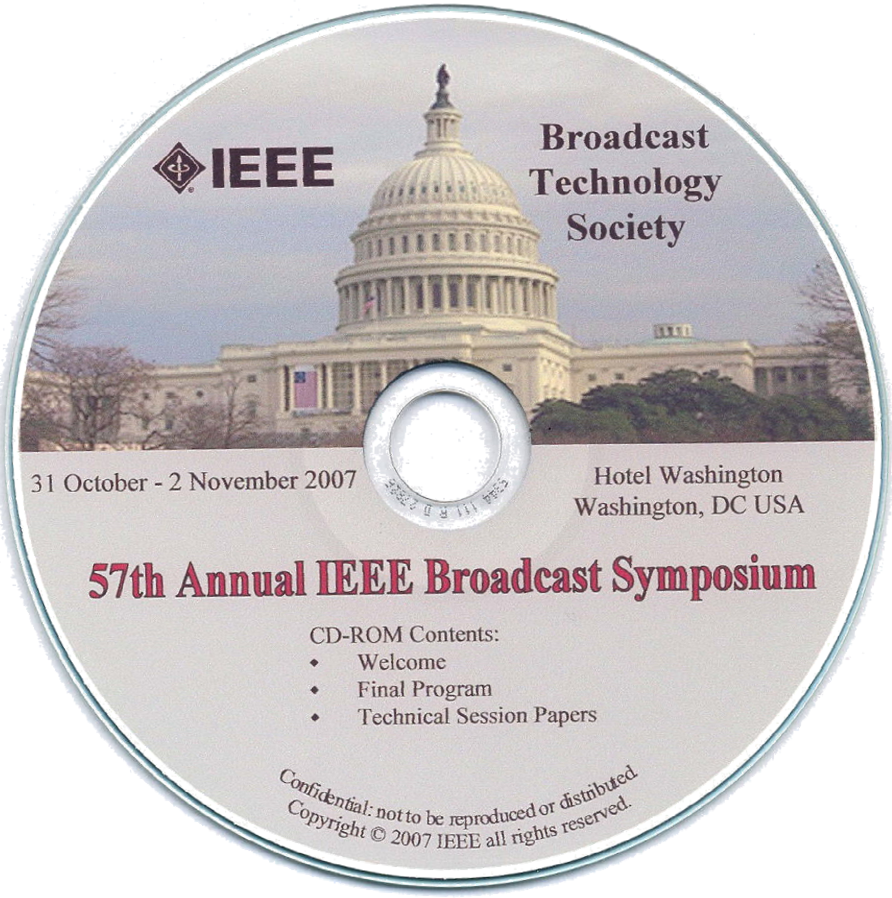
[3] ETSI, TR 102 401 v1.1.1, “Digital Video Broadcasting (DVB); Transmission to Handheld Terminals (DVB-H); Validation Task Force Report,” May 2005.

[4] G. Faria, j. A. Hendriksson, E. Stare, and P. Talmola, “DVB-H: Digital Broadcast Services to Handheld Devices,” Proceedings of the IEEE, vol. 94, no. 1, pp. 194–209, Jan. 2006.

[5] ITU-R Recommendation P.1546, “Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz,” 2003-2005.

[6] R. Schramm, “DVB-T C/N values for portable single and diversity reception,” EBU Technical review, 2004.

[7] TeamCast, “DVB-H calculator.” [Online]. Available: http://www.teamcast.com/en/maj-e/c2a2i9177/support/dvb-h-calculator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