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# TR 036

# TV PROGRAMME ACCOMMODATION IN A DVB-T2 MULTIPLEX FOR (U)HDTV WITH HEVC VIDEO CODING

TECHNICAL REPORT

VERSION 1.0

Geneva
March 2016

## Executive Summary

This report analyses the number of TV programmes that can be accommodated in a DVB-T2 multiplex when using HEVC video coding*. Several DTT scenarios are investigated for HDTV as well as for UHDTV formats.

A DVB-T2 multiplex together with HEVC video coding is capable of providing a satisfactory number of HD programmes for all of the investigated scenarios, as compared to the potential of previous DVB-T/MPEG-2 or AVC, or DVB-T2/AVC implementations. It amounts to 4 - 11 HD programmes for fixed roof-top reception and 3 - 7 HD programmes for portable reception, depending on the intended coverage and network scenario. Portable reception may include reception on tablets or smart phones, given that DVB-T2 capability were to be included in them.

The situation for UHDTV needs further scientific testing, as delivery standards are still being formulated. However, for the time being, for UHD-1 Phase 1 and the simplest UHD-1 broadcast profile, the number of programmes per multiplex can be estimated within a range.

An optimistic estimate for fixed reception scenarios may provide a multiplex capacity of 2 - 4 UHD-1 programmes. A more conservative estimate might reduce this to 1 programme per multiplex. For portable reception, even with optimistic assumptions only, 1 - 3 programmes per multiplex may be accommodated.

UHD-1 Phase 2 is not yet standardised and consequences on bit rates and on the number of programmes that may be accommodated in a DVB-T2 multiplex cannot accurately be estimated at present. There are two Phase 2 profiles being developed and the bit rate consequences of each are not yet known.

* Only the distribution of HDTV and UHDTV programmes over the Digital Terrestrial Television platform are considered in this report. The contribution of HDTV and UHDTV programmes has higher quality requirements and therefore the data rates are higher than the ones assumed in this report.

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# TV PROGRAMME ACCOMMODATION IN A DVB-T2 MULTIPLEX FOR (U)HDTV WITH HEVC VIDEO CODING

| *EBU Committee* | *First Issued* | *Revised* | *Re-issued* |
|---|---|---|---|
| TC | 2016 | | |

**Keywords:** HDTV, UHDTV, DVB-T2, HEVC video coding, Distribution scenario.

## 1. Introduction

This report analyses the number of TV programmes that can be accommodated in a DVB-T2 multiplex when using HEVC video coding. Several DTT scenarios are investigated for HD as well as UHD-1 TV formats (see § 4).

For both formats, HDTV and UHDTV-1 Phase 1, different approaches for estimating the data rates with HEVC coding are presented in § 2 and § 3, respectively.

§ 5 summarises the main findings of the report.

## 2. Data rates estimates for 720p/50, 1080i/25 and 1080p/50 HDTV with HEVC coding

Two different approaches for estimating the data rates for 720p/50, 1080i/25 and 1080p/50 HDTV with HEVC coding have been analysed in § 2.1 and § 2.2. The summary of the estimations of both approaches are presented in § 2.3.

### *2.1 Estimation Approach 1*

In an IRT study [1], HEVC data rates were estimated on the basis of current experience and practice with MPEG-2 and H.264 (AVC). The assumptions used for the estimations are:

- 6 Mbit/s per programme (video component) for HD with H.264.
  3 Mbit/s per programme (video component) for statistically multiplexed SD with MPEG-2.
- Statistical multiplexing gain for 4 (or more) programmes is typically 20% on average.
- Coding gain of HEVC with respect to H.264: 42% - 50%.
- Coding gain of H.264 with respect to MPEG-2: 50%.
- Coding gain of HEVC with respect to MPEG-2: 70%.

Table 1 shows the results of the estimations of data rates for the HD 720p/50 format at a picture quality usually available with IPTV which is also assumed for DTT. Figures for constant bit rate (CBR) as well as for variable bit rate (VBR), statistically multiplexed (statmux) modes are given.

**Table 1: Estimated video bit rate per programme for HD 720p/50 format**

| HD 720p/50, H.264 CBR | HD 720p/50, HEVC CBR | HD 720p/50, HEVC statmux (4 or more programmes/pool) |
|---|---|---|
| 6.0 Mbit/s | 3.5 Mbit/s | 2.8 Mbit/s |

For a HD 1080p/50 format, an increase of data rate of 10% maximum is expected. From laboratory experience [1], this increase can be considered negligible and a similar data rate for 1080p/50 can be assumed as for 720p/50, i.e., data rates of 3.0 - 3.3 Mbit/s onwards.

For each programme, a maximum of 800 kbit/s is assumed for audio and associated data. This results in the total required data rate per programme given in Table 2.

**Table 2: Estimated total bit rate per programme for HD 1080p/50 format (Estimation Approach 1)**

| HD 1080p/50, HEVC CBR | HD 1080p/50, HEVC statmux (4 or more programmes/pool) |
|---|---|
| 4.3 Mbit/s | 3.6 Mbit/s |

## *2.2 Estimation approach 2*

In a second approach, TDF considerations [2] assume that 5 HD programmes in 1080i/25 format can be accommodated in a DTT multiplex with a data rate of 24.9 Mbit/s in statmux mode[1] . For each programme, 1 Mbit/s is reserved for audio and associated data components; audio compression is based on AC3+ bit rates. This corresponds to 5 Mbit/s per programme or 4 Mbit/s per video component in VBR statistical mode. This approach assumed a statmux gain of 17.5% for 5 programmes; this is equivalent to 4.8 Mbit/s CBR video bit rate or 5.8 Mbit/s per programme[2].

**Table 3: Estimated total bit rate per programme for HD 1080i/25 format (e.g. DTT multiplex of 5 programmes)**

| HD 1080i/25, H.264 CBR | HD 1080i/25, H.264 statmux (5 programmes/pool) |
|---|---|
| 5.8 Mbit/s | 4.8 Mbit/s |

Data rates for 1080p HEVC are estimated in two steps. First, assuming a 42% coding gain as compared to H.264, a value of 2.8 Mbit/s is achieved with HEVC for 1080i/25 CBR video data rate. Second, a 20% increase is assumed for the step from 1080i to 1080p[3], which results in 3.35 Mbit/s for 1080p CBR video data rate. For programme associated data again 1 Mbit/s per programme is assumed, resulting in a total bit rate as given in Table 4.

**Table 4: Estimated total bit rate per programme for HD 1080p/50 format (Estimation Approach 2)**

| HD 1080p/50, HEVC CBR | HD 1080p/50, HEVC statmux (5 programmes/pool) |
|---|---|
| 4.4 Mbit/s | 3.8 Mbit/s |

[1] This assumption will become a reality in France starting from April 5th, 2016, with the nationwide switch from DVB-T/MPEG-2 to DVB-T/MPEG-4, together with a reduction from 8 to 6 multiplexes and an upgrade of the majority of the current programmes from SD to HD.

[2] This CBR bit rate is reached by latest generation encoders; a direct comparison with the values in Table 1 for approach 1 for 720p is not possible since these values are based on previous generation encoders.

[3] In theory, given a progressively scanned source, the bit rate needed for a given level of impairment for 1080p should be the same or less than that needed for 1080i because the interlacing is a simpler and less efficient form of compression compared to that used in content-adaptive digital compression systems. Actual bit rates will depend on the encoder design.

## 2.3 Summary of results of Approach 1 and Approach 2 estimations

Both approaches to estimating the data rates lead to similar results, as shown in Table 5.

**Table 5: Range of estimated total bit rate per programme for HD 1080p/50 format**

| HD 1080p/50, HEVC CBR | HD 1080p/50, HEVC statmux |
|---|---|
| 4.3 - 4.4 Mbit/s | 3.6 - 3.8 Mbit/s |

# 3. Data rate estimations for 2160p/50 UHDTV with HEVC coding

As a reference for UHD-1 TV, the 2160p/50 4k mode without HDR, HFR and Wide Colour Gamut options was chosen (equivalent to UHD-1 Phase 1)[4].

The required data rates for UHD-1 TV are still under investigation. Report ITU-R BT.2343 [3] summarizes various field tests that have been performed in the past; data rates between 17.5 Mbit/s and 40.2 Mbit/s are reported.

In ITU-R Recommendation BT.2073 [4] data rates between 30 Mbit/s and 40 Mbit/s are quoted, where these figures are regarded as an upper bound for "sufficiently high quality" and critical picture sequences. A value of 22.5 Mbit/s was used by TDF for the 4k field trials over DVB-T2 in Paris [3].

These largely diverging figures show that more investigations are required and a better understanding of the level of impairments associated with acceptability is needed. This is underlined by the observation that in ITU-R Rec. BT.2073 data rates of 10 - 15 Mbit/s for 2k HDTV 1080p/50 are quoted, whereas the results of § 2 show that for DTT, bit rates of around 4 Mbit/s may be sufficient.

It must be remembered that with the use of advanced compression systems, levels of impairment are very dependent on content, and thus what constitutes adequate quality will depend on the type of content used for the evaluation.

As a consequence, no unique data rate values can presently be assumed for 2160p/50 UHDTV with HEVC coding; rather a range should be used with an upper and a lower bound as discussed below.

## 3.1 Estimation of a data rate upper bound

A value of around 22.5 Mbit/s was used by TDF for the 4k Phase 1 field trials over DVB-T2 in Paris [3]. This value is chosen for the estimation of the data rate upper bound (see Table 8). In this case a statmux gain of 8% for two programmes in the multiplex has been assumed; it is the maximum number of programmes of 22.5 Mbit/s each that can be accommodated in a DVB-T2 multiplex.

## 3.2 Estimation of a data rate lower bound

For estimating the lower bound, three different methodologies are discussed in this report.

### 3.2.1 Methodology 1

Methodology 1, based on Approach 1 and its assumptions in §2.1 above, proposes the use of video data rates for 1080p/50 that are 4 times those given in Table 2; the estimated data rates for a UHD 2160p/50 programme are given in Table 6.

In this case a statmux gain of 20% for 4 programmes in the multiplex has been assumed as per the assumptions of Approach 1; it is the maximum number of programmes of 12.0 Mbit/s each that can

[4] UHDTV Phase 2 will include HDR, HFR and Wide Colour Gamut.

be accommodated in a DVB-T2 multiplex.

**Table 6: Lower bound of the estimated total bit rate per programme for UHD 2160p/50 format (Methodology 1)**

| UHD 2160p/50, HEVC CBR | UHD 2160p/50, HEVC statmux (4 programmes/pool) |
|---|---|
| 14.8 Mbit/s | 12.0 Mbit/s |

### 3.2.2 Methodology 2

Methodology 2 [2] for the lower bound starts with the HD CBR data rate of 6 Mbit/s for H.264, given in Table 1. For a 4k UHD video programme 24 Mbit/s is required (4 times 6 Mbit/s). Under this methodology, it is assumed for UHD-1:

- an HEVC gain of 60% [5]. This value seems realistic in 5 - 10 years time taking into account future progress in video compression encoder design techniques, and
- a statmux gain of 12% for 3 programmes per multiplex. The number of programmes per multiplex is linked to the foreseen DVB-T2 mode for France, which will be limited to a bit rate of around 33 Mbit/s per multiplex.

This results in the figures given in Table 7 for the lower bound. 800 kbit/s for programme associated audio and data is assumed (but this could be decreased to 666 kbit/s if Next Generation Audio were to be introduced in advance of UHDTV Phase 2).

**Table 7: Lower bound of the total bit rate per programme for UHD 2160p/50 format (Methodology 2)**

| UHD 2160p/50, HEVC CBR | UHD 2160p/50, HEVC statmux (3 programmes/pool) |
|---|---|
| 10.4 Mbit/s | 9.25 Mbit/s |

### 3.2.3 Methodology 3

Methodology 3 to estimate the UHD-1 TV CBR bit rate gives lower bound values that are similar to those given by Methodology 2:

- Consider a video component bit rate of 3.4 Mbit/s for 1080p/50 (taken from Table 4: 4.4 Mbit/s with 1 Mbit/s for associated audio and data).
- Assume an HD to UHD scaling bit rate ratio of 2.8 in HEVC compressed domain [6].
- This results in a video component bit rate of 9.6 Mbit/s.
- Adding 800 kbit/s for programme associated audio and data very similar results are achieved for the lower bound as given above in Table 7.

### 3.2.4 Summary of results of the three methodologies

In Table 8 the results of the different methodologies are collected.

**Table 8: Upper and lower bound of estimated total data rates per programme for UHD 2160p/50 format**

| | UHD 2160p/50, HEVC CBR | UHD 2160p/50, HEVC statmux |
|---|---|---|
| lower bound | 10.4 - 14.8 Mbit/s | 9.25 - 12.0 Mbit/s |
| upper bound | 22.5 Mbit/s | 20.7* Mbit/s |
| (* with a statmux gain of 8% for two programmes in the multiplex) | | |

The results of the three methodologies used for the lower bound data rate differ remarkably and need further investigation. For the time being, the larger value for the lower bound can be regarded as being realistic for existing video compression technology in a short to medium term whereas the smaller value may be interpreted as a final asymptotic HEVC gain in 5 - 10 years time, taking into account future progress in video compression techniques[5].

# 4. Number of programmes per multiplex with HEVC coding for various DTT scenarios

In EBU Tech 3348 [7] several DTT scenarios based on DVB-T2 are described. Using those same scenarios, the numbers of HD and UHD programmes that may be accommodated in a multiplex are calculated.

For the sake of clarity, the statistical multiplex gain figures reported in [6] are used; these are reproduced in Table 9. A particular value is given for each number of programmes per multiplex. These are more detailed than the representative values used in § 2 and § 3. It should be kept in mind that these figures are average values obtained from experience and that they may differ slightly in individual cases.

**Table 9: Statistical multiplexing gain as a function of the number of programmes per multiplex (reproduced from [6])**

| # Programmes per multiplex | Statistical multiplexing gain (%) |
|---|---|
| 1 | 0 |
| 2 | 8 |
| 3 | 12 |
| 4 | 15 |
| 5 | 17.5 |
| 6 | 19 |
| 7 | 21 |
| 8 | 23 |
| 9 | 24 |
| 10 | 25 |

Table 10 overleaf shows the results for fixed reception scenarios and Table 11 shows the results for portable and mobile reception scenarios.

Note that in both these tables the numbers of programmes are given to the first decimal, although in practice only an integer number of programmes can be accommodated.

Furthermore, results for 720p/50 are assumed to be identical with those for 1080p/50.

[5] However, the MPEG/ITU-T group is likely to commence with the development of a more advanced compression system than HEVC soon, but it is too early to say whether it will be a candidate for delivery of UHD-1 Phase 2.

**Table 10: Overview of the rooftop implementation scenarios**

| **Implementation** | **Fixed rooftop reception MFN (UK mode)** | **Fixed rooftop reception (maximum coverage area extension)** | **Fixed rooftop reception Limited area SFN (GE06 Allotment)** | **Fixed rooftop reception Large area SFN** |
|---|---|---|---|---|
| **Scenario** | **1** | **2** | **3a** | **3b** |
| Bandwidth | 8 MHz | 8 MHz | 8 MHz | 8 MHz |
| FFT mode | 32k | 32k | 32k | 32k |
| Carrier mode | Extended | Extended | Extended | Extended |
| Scattered Pilot Pattern | PP7 | PP2 | PP4 | PP2 |
| Guard interval | 1/128 (28 µs) | 1/8 (448 µs) | 1/16 (224 µs) | 1/8 (448 µs) |
| Modulation | 256-QAM | 16-QAM | 256-QAM | 256-QAM |
| Code rate | 2/3 | 2/3 | 2/3 | 2/3 |
| C/N | 20.0 dB | 11.6 dB | 20.8 dB | 21.2 dB |
| Data rate | 40.2 Mbit/s | 16.7 Mbit/s | 37.0 Mbit/s | 33.4 Mbit/s |
| # programmes HDTV 1080p/50 HEVC | 11.4 - 11.7 | 4.3 - 4.4 | 10.4 - 10.8 | 9.5 - 9.7 |
| # programmes UHDTV 2160p/50 HEVC Lower bound | 2.9 - 4.5 | 1.1 - 1.6 | 2.7 - 4.2 | 2.4 - 3.6 |
| # programmes UHDTV 2160p/50 HEVC Upper bound | 1.8 | 0.7 | 1.6 | 1.5 |

**Table 11: Overview of the portable and mobile implementation scenarios**

| **Implementation** | **portable reception (maximum date rate)** | **portable reception (maximum date rate, alternative)** | **portable reception (maximum coverage area extension)** | **portable reception (optimum spectrum usage)** | **portable and mobile reception (common usage of MUX by different services)** | |
|---|---|---|---|---|---|---|
| Scenario | 4a | 4b | 5 | 6 | 8 | |
| | | | | | high data rate | low data rate |
| Bandwidth | 8 MHz | 8 MHz | 8 MHz | 8 MHz | 8 MHz | |
| FFT mode | 16k | 32k | 16k | 16k | 8k | |
| Carrier mode | Extended | Extended | Extended | Extended | Extended | |
| Scattered Pilot Pattern | PP3 | PP4 | PP3 | PP1 | PP1 | |
| Guard interval | 1/8 (224 µs) | 1/16 (224 µs) | 1/8 (224 µs) | 1/4 (448 µs) | 1/4 (224 µs) | |
| Modulation | 64-QAM | 64-QAM | 16-QAM | 64-QAM | 64-QAM | 16-QAM |
| Code rate | 2/3 | 2/3 | 1/2 | 2/3 | 2/3 | 1/2 |
| C/N | 17.9 dB | 17.9 dB | 9.8 dB | 18.3 dB | 18.3 dB | 10.2 dB |
| Data rate | 26.2 Mbit/s | 27.7 Mbit/s | 13.1 Mbit/s | 22.6 Mbit/s | 22.4 Mbit/s (max) | 11.2 Mbit/s (max) |
| # programmes HDTV 1080p/50 HEVC | 7.1 - 7.3 | 7.5 - 7.8 | 3.3 - 3.4 | 6.0 - 6.2 | 6.0 - 6.2 | 2.7 - 2.8 |
| # programmes UHDTV 2160p/50 HEVC Lower bound | 1.8 - 2.7 | 1.9 - 3.0 | 0.9 - 1.3 | 1.5 - 2.4 | 1.5 - 2.3 | 0.8 - 1.1 |
| # programmes UHDTV 2160p/50 HEVC Upper bound | 1.2 | 1.2 | 0.6 | 1.0 | 1.0 | 0.5 |

# 5. Conclusions

The overview shows that a DVB-T2 multiplex together with HEVC video coding is capable of providing a satisfactory number of HD programmes for all of the described scenarios, as compared to the potential of previous DVB-T/MPEG-2 or AVC implementations. It amounts to 4 - 11 HD programmes for fixed roof-top reception and 3 - 7 HD programmes for portable reception depending on the intended coverage and network scenario. These figures can be regarded as sufficiently stable estimates.

The situation for UHDTV needs further scientific testing, as delivery standards are still being formulated. However, for the time being, for UHD-1 Phase 1 and the simplest UHD-1 broadcast profile, the number of programmes per multiplex can only be estimated within a range.

An optimistic estimate for fixed reception scenarios may provide a multiplex capacity of 2 - 4 programmes. A more conservative estimate might reduce this to 1 programme per multiplex. For portable reception, even with optimistic assumptions only, 1 - 3 programmes per multiplex may be accommodated.

For portable and mobile reception, it is likely that no satisfactory provision of programme variety can be achieved with DTT, given the spectrum available for broadcasting at present. On the other hand, it is still to be evaluated whether UHDTV transmissions for portable and mobile reception are reasonable.

UHD-1 Phase 2 is not yet standardised and consequences on bit rates and on the number of programmes that may be accommodated in a DVB-T2 multiplex cannot accurately be estimated at present. There are two Phase 2 profiles being developed and the bit rate consequences of each are not yet known.

A future UHDTV Phase 3 (8k) system may be possible in the next decade, but the delivery of such a format would require a next generation modulation system going beyond DVB-T2.

# 6. References

[1] IRT, Internal communication in EBU project team SMR-BNP, Feb. 2015

[2] TDF, Internal communication in EBU project team SMR-BNP, Oct. 2015

[3] ITU-R, Rep. BT.2343-0, “Collection of field trials of UHDTV over DTT networks”, Geneva, 2015

[4] ITU-R, Rec. BT.2073-0, “Use of the high efficiency video coding (HEVC) standard for UHDTV and HDTV broadcasting”, Geneva, 2015

[5] ISO/IEC JTC1/SC29/WG11 N14420; “Report on HEVC compression performance verification testing “, April 2014, Valencia

[6] ZetaCast, Technical Evolution of the DTT Platform; An independent report by ZetaCast, commissioned by Ofcom; Jan. 2012

[7] EBU Tech 3348, v.4.1.1, “Frequency and network planning aspects of DVB-T2”, Oct. 2014