Local Television Capacity Assessment

An independent report by ZetaCast, commissioned by Ofcom

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CONTENTS

1. Executive Summary and Conclusions

This report provides a technical review of the likely capacity required for local television services within a low-capacity DVB-T multiplex. The main findings are as follows:

Video and Audio – Formats and Compression

1. In order to maximise the utilisation of the installed base of DTT receivers, SDTV at full resolution or subsampled horizontally by ¾ or ⅔ was considered:
    - 720 pixels by 576 lines
    - 544 pixels by 576 lines
    - 480 pixels by 576 lines
2. Video and Audio Compression technologies considered were:
    - MPEG-2 video
    - MPEG-1 Layer II audio
3. Statistical multiplexing:
    - Gains dependent on number of channels in the stat mux group and architecture
    - For a 2 channel group the gain assumed was of 8%
    - For a 3 channel group in a re-multiplexing scenario the gain assumed was of 11%
    - For a 3 channel group in a multiplexing scenario the gain assumed was of 12%

Terrestrial Channel and Coding Modulation

4. DVB-T with FEC ⅔ or ¾ were used in the scenarios explored and defined as Mode 1 and Mode 2 respectively
    - ¾ gives higher bit rates, with a potential impact of lowering coverage

Bit Rates Required for Local TV

5. Four possible architectures were considered, each with different trade-offs between complexity/cost and video resolution that is likely to be practical.
6. Within each architecture the choice of modulation mode provides a further option to trade-off bit rate against coverage
    - Scenario 1: All services at CBR. This is likely to be the least costly architecture to implement, but it imposes the greatest constraints on the video resolution that is likely to be practical
        - Mode 1: may provide sufficient capacity if a higher than normal level of artefact was acceptable, even if all services were sub-sampled to ⅔ resolution
        - Mode 2: Would provide sufficient capacity if all services were subsampled to ¾ resolution
    - Scenario 2: National services centrally statmuxed, local service at CBR
        - Mode 1: Would provide sufficient capacity if the local service was subsampled to ¾ resolution and the national services to ⅔ resolution
        - Mode 2: Would provide sufficient capacity if all services were subsampled to¾ resolution
    - Scenario 3: All services re-multiplexed locally
        - Mode 1: Would provide sufficient capacity if the local service was subsampled to ¾ resolution and the national services subsampled to ⅔ resolution

    - Mode 2: May provide sufficient capacity if the local service was encoded at full resolution and the national services were subsampled to ¾ resolution

- Scenario 4: All services locally statmuxed. This scenario could be considered the converse of Scenario 1. It imposes the least constraints on the video resolution but it is likely to be the most costly architecture to implement
    - Mode 1: Would provide sufficient capacity if all services were subsampled to ¾ resolution
    - Mode 2:May provide sufficient capacity if the local service was encoded at full resolution and the national services were subsampled to ¾ resolution

7. Scenarios 2 and 3 both appear to provide a "sweet spot" in terms of complexity/cost versus benefit

Subtitling and Audio Description

8. The provision of subtitling and audio description were considered separately to the audiovisual components, and assumed to apply to both national and local TV services.
9. If practical to implement, both subtitles and audio description could be included in some of the different scenarios
    - Bit rate requirements assumed for subtitling are 25 kbit/s per service and receiver-mixed audio description at 64 kbit/s per service
    - In Scenario 1
        - Mode 1: This modulation mode is unlikely to be able to support the addition of either subtitling or audio description at any video resolution
        - Mode 2: Both subtitling and audio description could be supported if the local service was subsampled to ¾ resolution and the national services were subsampled to ⅔ resolution
    - In Scenario 2
        - Mode 1: Subtitling could be supported if the local service was subsampled to ¾ resolution and the national services were subsampled to ⅔ resolution. Both subtitling and audio description could be supported if all services were subsampled to ⅔ resolution
        - Mode 2: Both subtitling and audio description could be supported if all services were subsampled at ¾ resolution
    - In Scenario 3
        - Mode 1: Both subtitling and audio description could be supported if the local service was subsampled to ¾ resolution and national services to ⅔ resolution
        - Mode 2: Both subtitling and audio description could be supported if the local service was encoded at full resolution and the national services were subsampled to ¾ resolution
    - In Scenario 4
        - Mode 1: Both subtitling and audio description could be supported if the local service was subsampled to ¾ resolution and the national services were subsampled to ⅔ resolution
        - Mode 2: Both subtitling and audio description could be supported if the local service was encoded at full resolution and the national services were subsampled to ¾ resolution

2. Introduction

In accordance to the DCMS Framework for Local TV in the UK [1], Ofcom is expecting to license a number of local television services from mid-2012, with launch expected in the second half of 2013.

The anticipated model is for a single multiplex operator (MuxCo) to be licensed to provide an additional multiplex at a number of established transmitter locations around the UK. The multiplex would need to use a robust transmission mode to achieve reasonable coverage and would therefore be able to accommodate a small number of programme services [2].

MuxCo would be under an obligation to make available sufficient capacity within the multiplex for one local programme service at each location. Otherwise MuxCo will be able to utilise the remainder of the multiplex capacity in whatever way they desired: for example by sub-leasing capacity to other programme service providers. There is an expectation that the local multiplex would be able to accommodate three programme services in total.

This report provides an analysis of the capacity required to transmit three TV services from local transmitting stations around the UK under this model.

Assumptions

The assumptions supporting this report are:

1. Number of audio-visual services considered
    a. One local (unique to each transmission site location)
    b. Two national (the same at every transmission site location)
2. In addition to audiovisual services, the local multiplexes will cross-carry SI/PSI and EIT with the national multiplexes
3. Local programme feeds are presented at each transmitter site for insertion into the local multiplex
4. Possibility of adding subtitling and audio description
5. Video and audio compression technology
    a. MPEG-2 for video
    b. Stereo MPEG-1 Layer II for audio
6. Channel coding and modulation parameters
    a. Constellation: QPSK
    b. Forward Error Correction rate: ⅔ or ¾
    c. Guard Interval: 1/32
    d. Carriers: 8K
7. A minimum of 20 transmission sites

3. Video and Audio - Format and Compression

Video Resolution

The video resolution of the Standard Definition format is 720 pixels x 576 lines. However, this is sometimes subsampled horizontally, e.g. to 544, 480 or 352 pixels x 576 lines, in order to reduce the required bit rate without introducing artefacts.

Video and Audio Compression

MPEG-2 Video

Current SDTV video services in the UK are broadcast using MPEG-2 video compression.

MPEG-2 was published in 1995 as ISO/IEC 13818-2 and ITU-T Recommendation H.262 [3]. The video compression standard was added to the DVB audio-visual coding standard, ETSI TS 101 154 [5].

This technology is relatively mature and is unlikely to develop significantly in the future. This report therefore assumes that no major improvement in MPEG-2 encoder efficiency will occur.

MPEG-1 Layer II (or MPEG-2 Layer II) Audio

SDTV programming is broadcast with only stereo sound, using "Layer 2" audio as the compression format.

"Layer 2" audio (MPEG-1 Layer II or MPEG-2 Layer II) is an audio compression format defined by ISO/IEC 13818-3 [4] and added to the DVB audio-visual coding standard, TS 101 154.

Like MPEG-2 video, this technology is mature and is unlikely to develop significantly in the future. This report therefore assumes that no major improvement in MPEG-1 Layer 2 encoder efficiency will occur.

Statistical Multiplexing

In a constant bit-rate system, each video service in the multiplex has a fixed allocation of data rate regardless of the nature of the video content. When statistical multiplexing is used, a lower data rate is allocated when the video is easy to encode, such as a head and shoulders shot of a news presenter sitting in a studio. A higher data rate is allocated when the video content becomes more demanding, e.g. a sports clip within the news programme.

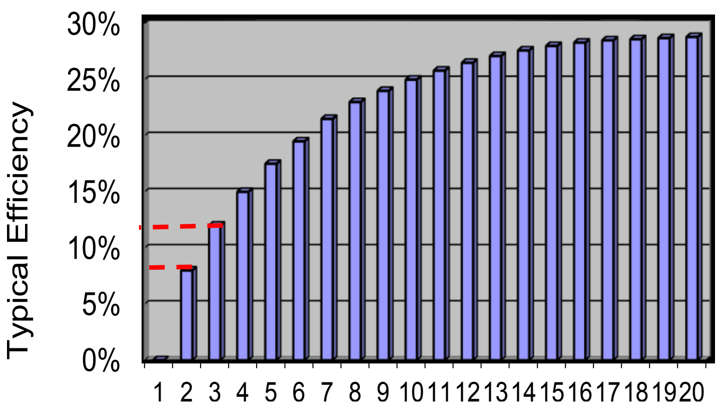

Figure 1: Typical efficiency gains through statistical multiplexing

The improved coding efficiency due to sharing the multiplex capacity increases with the number of channels, as the peaks and troughs of bit-rate demand across the channels average each other out more effectively. The exact efficiency gain is dependent on both the nature of the video content across all of the channels and also the details of the implementation, but gains can be typically expected to asymptotically approach a value of around 30% for large numbers of channels.

To a first approximation, the savings are independent of the resolution of the video and the choice of compression algorithm. The graph in Figure 1 above is indicative of the typical benefits that can be expected.

4. Terrestrial Channel Coding and Modulation

DVB-T

DVB-T [10] was developed in the mid to late 1990s, building on work conducted in a number of European research laboratories in the preceding decade. It uses a multicarrier modulation scheme known as Coded Orthogonal Frequency Division Multiplexing (COFDM). This gives excellent immunity to multipath reception, as well as resistance to interference from analogue television transmission systems. Two variants of the system were defined in the DVB-T specification, using 1705 ("2K") or 6817 carriers ("8K"). The former system gives better performance for mobile reception; the latter allows rejection of very long echoes which occur in a Single Frequency Network (SFN), i.e. a network of multiple transmitters working on the same frequency.

On each carrier, modulation constellations from QPSK up to 64QAM are allowed. DVB-T has a number of overheads which reduce data capacity, but aid performance and synchronisation in the receiver. These are the guard interval and assorted 'pilots'. The amount of capacity allocated to pilots is significantly higher than the minimum that is theoretically required, partly because it simplifies the design of receivers.

The DVB-T parameter set currently in use by the UK's post-switchover national standard definition PSB multiplexes is shown below and yields a total capacity of approximately 24.1 Mbit/s per multiplex.

- 64QAM modulation
- 1/32 Guard Interval
- ⅔ FEC Rate
- 8K FFT

For local TV, the robustness of the transmission is a key requirement. The DVB-T parameter sets considered for local TV are as shown in the table below, giving higher total available bit rates as FEC rate increases. However, there is a potential trade-off between the bit rate shown below and coverage area, in that increasing the bit rate may decrease the geographical area covered by the transmission. The following parameter sets yield a capacity of approximately 8.04 Mbit/s (FEC ⅔) and 9.05 Mbit/s (FEC ¾):

- QPSK modulation
- 1/32 Guard Interval
- ⅔ or ¾ FEC Rate
- 8K FFT

DVB-T2

DVB-T2 [11] is the second-generation DVB terrestrial broadcasting system. Like DVB-T, it uses COFDM, but with up to 32K carriers. Using more carriers permits a shorter percentage guard interval, and hence a reduced loss of data capacity, for the same length of echoes as with DVB-T. It also has a lower overhead for pilots, closer to the theoretical minimum required to fully exploit a given guard interval.

DVB-T2 allows constellations of up to 256QAM per carrier, thus allowing a greater bitrate capacity in each 8MHz UHF channel. DVB-T2 follows DVB-T in inheriting its error correction scheme from the corresponding satellite system, in this case DVB-S2 [9]. The low-density parity-check (LDPC) codes are well-suited to use in applications that approximate to an additive white Gaussian noise (AWGN) channel, such as line-of-sight satellite reception. However, they are not as well-suited to terrestrial reception, where COFDM modulation is working in a channel with strong multipath reception. To partially overcome this, DVB-T2 defines 'rotated constellations'. These trade a small loss in AWGN performance for a significant gain in multipath performance. DVB-T2 can yield approximately 50% more efficiency for comparable levels of robustness to DVB-T.

It is however assumed that DVB-T2 will not be used for transmission of local TV services; therefore it has not been included in the system architecture scenarios described in section 5.

5. Bit Rates required for Local TV

Multiplex Capacity

The SDTV services will be encoded using MPEG-2 and carried on a DVB-T multiplex with robust transmission parameters. While the decision on the specific variant will be made by Ofcom following consultation, one candidate mode that has been assumed for the purposes of producing indicative coverage maps is QPSK rate ⅔, giving a total capacity of approximately 8.04 Mbit/s. If higher bit rates are required, one possibility would be to increase the FEC rate to the next step, i.e. ¾, yielding a multiplex with total capacity of approximately 9.05 Mbit/s. However, this would potentially impact on the transmission coverage area by reducing it somewhat. The table below summarises the two modes, which will be referred further in this document as Mode 1 and Mode 2.

	Mode 1	Mode 2
Modulation	QPSK	QPSK
Guard Interval	1/32	1/32
FEC rate	⅔	¾
FFT	8K	8K
Total available	**8.04Mbit/s**	**9.05Mbit/s**

Table 1: Modulation mode variants considered for Local TV

Assuming that there is no requirement for the carriage of interactive data (e.g. MHEG applications), approximately **0.6 Mbit/s** would be required for non-programme content:

- MPEG Program Specific Information (PSI), DVB Service Information (SI): 0.3 Mbit/s
- Null packets: 0.3 Mbit/s

The remaining 7.44 Mbit/s (Mode 1) or 8.45 Mbit/s (Mode 2) is available for programme content.

Bit Rate per Service

Assuming that full resolution broadcast quality is provided when 9 services share a 24.1 Mbit/s (22.6 Mbit/s available for programme content) multiplex, after taking statmuxing effects into account, this corresponds to an equivalent CBR of approximately **3.4 Mbit/s** per service. This assumes a "normal" mixture of broadcast content. If the channel carried predominantly sports material for example then a higher bit rate may be required, whilst conversely a lower bit rate is likely to suffice for a channel that predominantly carries material that is significantly less challenging to encode, such as studio shots of a news reader.

As the bit rate is reduced below this value, the coding artefacts can become increasingly visible. If significantly lower bit rates are required, then a reduction in the horizontal resolution would probably give a more subjectively pleasant result in terms of trade-off between softness of the picture and visibility of coding artefacts.

To a first approximation, the bit rate required for the video component is approximately proportional to the number of pixels/second. However, the relationship is not quite linear and subsampling the video does not reduce the bit rate required for non-video components of the service.

The following bit rates will be assumed for subsampled services in this report:

Full resolution (720 pixels)	¾ Resolution (544 pixels)	⅔ Resolution (480 pixels)
3.4 Mbit/s	2.8 Mbit/s	2.5 Mbit/s

Table 2: Bit rate per service derived from resolution reduction

SUBTITLING AND AUDIO DESCRIPTION

Television subtitling has been around for more than two decades, either for the translation of the foreign spoken word or as same-language subtitling.

Guidelines for good subtitling practice are well-established [14][12] and, with technical developments and increasing market competition, there are now a number of choices for the provision of subtitling services, including network authoring, which is a cost effective way to produce subtitles. However, as these still involve having a person carrying out the authoring, the costs associated with delivering subtitles are not insignificant.

The authoring and production of audio description services is a considerably more labour-intensive task. Audio description is delivered to the television or set-top box as an additional (second) audio channel to a service, and can be either 'receiver mixed' or 'broadcast mixed'.

With broadcast-mixed audio description, the additional audio stream is a full bit-rate audio channel, containing both the original soundtrack and the descriptions mixed into it. While broadcast-mixed audio description is commonly supported by domestic receivers, it is more demanding on the capacity required per channel.

With receiver-mixed audio description, the second audio stream consists of the audio description narration only (mono) and it is therefore more bandwidth efficient. Receiver-mixed audio description is often considered preferable for viewers because it allows them to control the relative volume level of the audio description, and it can be fed to headphones so the viewer can hear it independently from the original service soundtrack. The DTG Usability and Accessibility Guidelines [12] specifies receiver-mixed audio description as best practice, as does the 2007 Digital Europe "Industry Self-Commitment" [13], signed by CE manufacturers such as Samsung and Panasonic. However, large scale availability of receiving equipment supporting receiver-mixed feature may still be an issue to consider when calculating capacity availability.

The bit rates per service required to deliver audio description required are approximately as follows:

- Broadcast-mixed: 192 - 256 kbit/s
- Receiver-mixed (mono): 64 kbit/s

Subtitling and audio description may not be a regulatory requirement when providing local TV services. Should these services be required, however, the assumptions for bit rates in the calculations used in this report are:

- Subtitling: 25 kbit/s per service
- Audio description: 64 kbit/s (receiver-mixed) per service

POSSIBLE ARCHITECTURES

There are a number of possible system architectures that can be explored in order to deliver TV services to local transmitting stations around the UK. There are four scenarios described in the next sub-sections which provide examples of architectures that could be used. In these scenarios, the total bit rate required to allow three TV services to fit into the DVB-T multiplex will vary depending on the choice of video quality, complexity/cost of infrastructure and coverage.

All scenarios described in the next sub-sections explore bite rate availability in modulation Modes 1 and 2 (FEC ⅔ and ¾) if:

1. All services are encoded at full resolution
2. The local service is encoded at full resolution and the national services are encoded at ¾ resolution
3. All services are encoded at ¾ resolution
4. The local service is encoded at ¾ resolution and the national services are encoded at ⅔ resolution
5. All services are encoded at ⅔ resolution

Whilst the remaining capacity shown in the tables in the sub-sections describing the 4 scenarios excludes subtitles and audio description, it does indicate the video resolutions and modulation modes in which subtitles or both subtitles and audio description could be supported.

The possibility of adding subtitles and audio description in each of the sub-scenarios will therefore be described in the tables by the following:

- Subtitles only = S
- Subtitles and Audio Description = SAD

In all cases, distribution from the national headend to the transmission sites is assumed to use satellite.

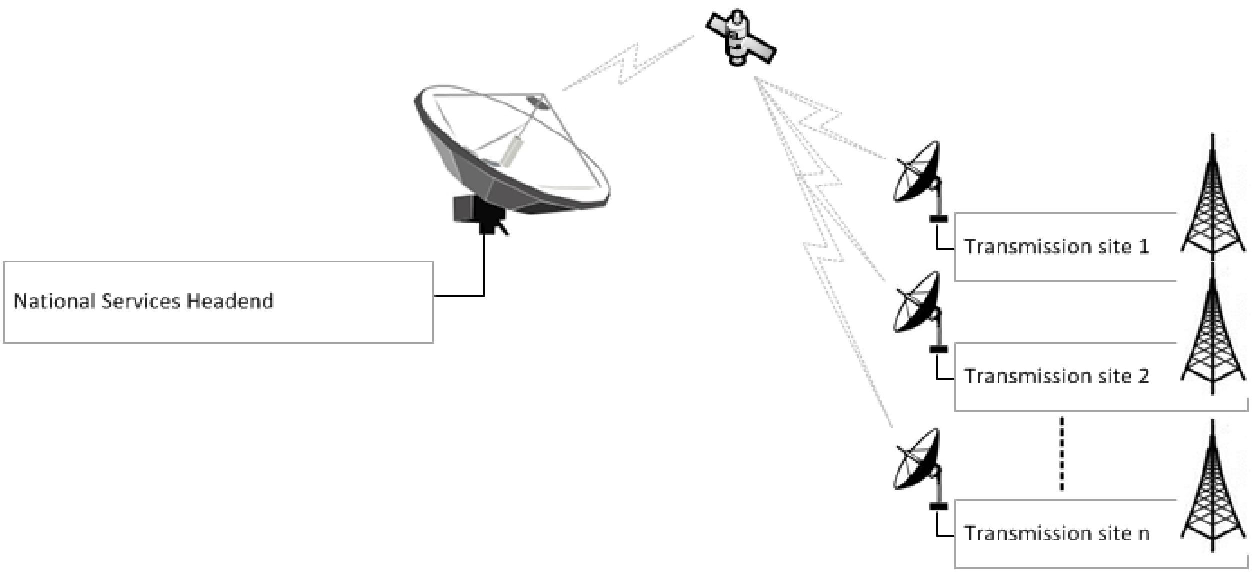

Figure 2: Overall satellite distribution system

NB: There are other possible distribution solutions available which have not been considered in this report.

SCENARIO 1: ALL SERVICES INSERTED LOCALLY AT CBR (NO STATISTICAL MULTIPLEXING)

Under this scenario, the two national services are encoded at CBR at a central headend and distributed via satellite to the local transmission sites. At the local sites, the transport stream containing the two national services is multiplexed with the single local service (also encoded at CBR), which are then modulated for terrestrial transmission.

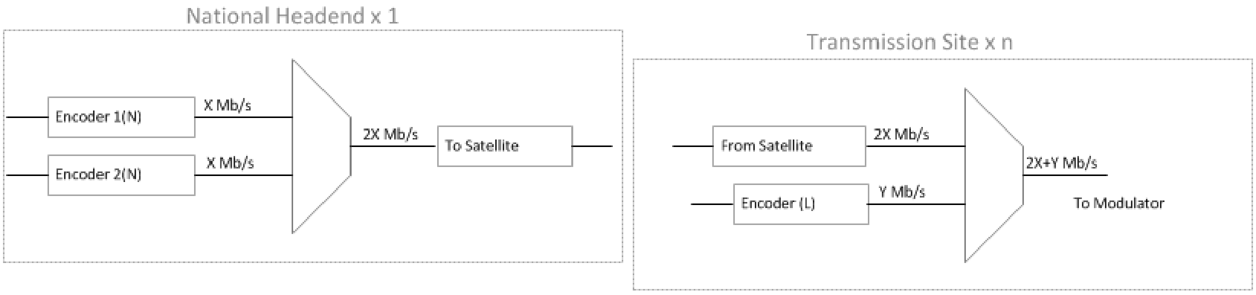

Figure 3: Basic Architecture 1 - All services locally inserted at CBR

This is likely to be the least costly system architecture, since there is no requirement for statistical multiplexing at any point. The drawback however is that it requires the highest bit rate to represent the 3 services of all the architectures considered.

The table below shows the bit rate availability (in Mbit/s) in both modulation modes versus video resolution.

	All services at full res	*Local: full res National: ¾ res*	*All services at ¾ res*	*Local: ¾ res National: ⅔ res*	*All services at ⅔ res*
CBR x 3	10.20	9.00	8.40	7.80	7.50
Total bit rate (incl PSI/SI)	10.80	9.60	9.00	8.40	8.10
Remaining capacity (Mode 1)	-2.76	-1.56	-0.96	-0.36	-0.06
Remaining capacity (Mode 2)	-1.75	-0.55	**0.05**	**0.65** SAD	**0.95** SAD

Table 3: Scenario 1 capacity availability (in Mbit/s) in modulation Modes 1 and 2

Neither Mode 1 (FEC ⅔) nor Mode 2 (FEC ¾) would provide sufficient capacity to allow full resolution services to be broadcast. Indeed, Mode 1 modulation is unlikely to provide sufficient capacity even if all services were subsampled to ⅔ resolution. However, Mode 2 appears to provide sufficient capacity if all services are subsampled to ¾ resolution.

SUBTITLING AND AUDIO DESCRIPTION

Mode 1 is unlikely to be able to support the addition of either subtitling or audio description at any video resolution. However, both subtitling and audio description could be supported by Mode 2 if the local service was subsampled at ¾ resolution and the national services at ⅔ resolution.

SCENARIO 2: NATIONAL SERVICES CENTRALLY STATMUXED AND LOCAL SERVICEENCODED LOCALLY AT CBR

Under this scenario, the two national services are encoded at VBR at a central headend with statistical multiplex gains of about 8%, and distributed via satellite to the local transmission sites. At the local transmission sites, the transport stream containing the two statistically multiplexed national services is multiplexed with the single local service (encoded at CBR), which are then modulated for terrestrial transmission.

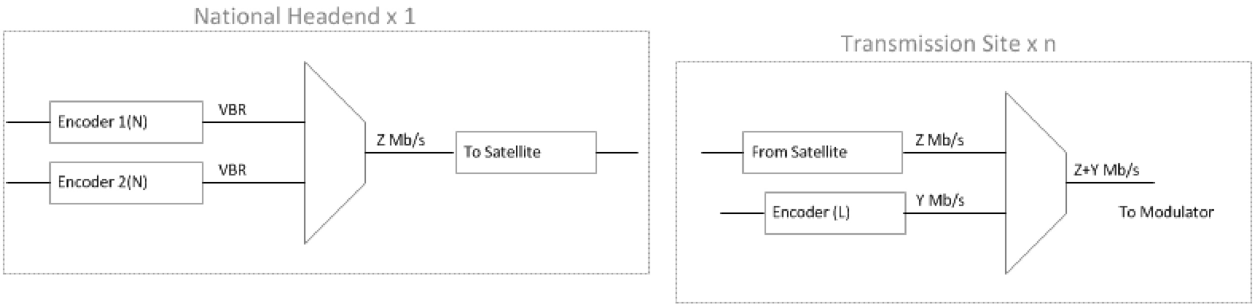

Figure 4: Basic Architecture 2 - National services centrally statmuxed, local services locally encoded at CBR

Since under this architecture there is a requirement for statistical multiplexing at a centralised mux for the national services, this system is likely to be costlier that the one in Scenario 1. In terms of capacity, it requires the second highest bit rate to represent the 3 services of the architectures considered.

The table below shows the bit rate availability (in Mbit/s) in both modulation modes versus video resolution.

	All services at full res	*Local: full res National: ¾ res*	*All services at ¾ res*	*Local: ¾ res National: ⅔ res*	*All services at ⅔ res*
CBR x 1	3.40	3.40	2.80	2.80	2.50
CBR x 2	6.80	5.60	5.60	5.00	5.00
Statmux x 2	6.26	5.15	5.15	4.60	4.60
Total bit rate (incl PSI/SI)	10.26	9.15	8.55	8.00	7.70
Remaining capacity (Mode 1)	-2.21	-1.11	-0.51	**0.04**[S]	**0.34**[SAD]
Remaining capacity (Mode 2)	-1.21	-0.10	**0.50**[SAD]	**1.05**[SAD]	**1.35**[SAD]

Table 4: Scenario 2 capacity availability (in Mbit/s) in modulation Modes 1 and 2

Neither Mode 1 (FEC ⅔) nor Mode 2 (FEC ¾) modulation would provide a sufficient capacity to allow full resolution services to be broadcast. However, Mode 1 modulation would be likely to provide sufficient capacity if the local service was subsampled at ¾ resolution and the national services were subsampled to ⅔ resolution. Mode 2 appears to provide sufficient capacity if all services are subsampled to ¾ resolution.

SUBTITLING AND AUDIO DESCRIPTION

Mode 1 would be able to support the addition of subtitling if the local service was subsampled at ¾ resolution and the national services subsampled to ⅔ resolution. However, in Mode 2, both subtitling and audio description could be supported if all services were subsampled to ¾ resolution.

Scenario 3: All services locally re-multiplexed

Under this scenario, the two national services are encoded at a central headend and distributed via satellite to the local transmission sites. At the local transmission sites, the transport stream containing the two multiplexed national services is statistically multiplexed with the single local service (encoded at VBR), which are then modulated for terrestrial transmission.

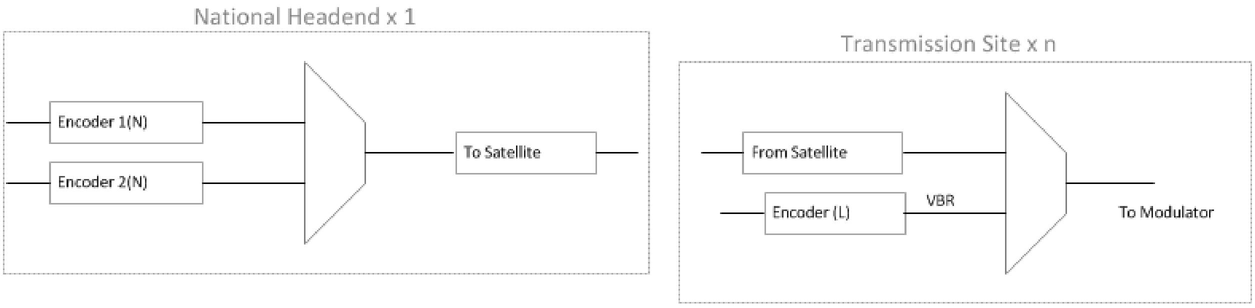

Figure 5: Basic Architecture 3 - National services centrally statmuxed and re-multiplexed with local service at the local transmission site

Under this architecture there is requirement for statistical multiplexing at the local transmission site, via a dynamic re-multiplexer, e.g. the CherryPicker™. The statistical multiplexing gains assumed under this scenario are of about 11%.

The table below shows the bit rate availability (in Mbit/s) in both modulation modes versus video resolution.

	All services at full res	*Local: full res National: ¾ res*	*All services at ¾ res*	*Local: ¾ res National: ⅔res*	*All services at ⅔ res*
CBR x 3	10.20	9.00	8.40	7.80	7.50
Statmux x 3	9.08	8.01	7.48	6.94	6.68
Total bit rate (incl PSI/SI)	9.68	8.61	8.08	7.54	7.28
Remaining capacity (Mode 1)	-1.64	-0.57	-0.03	**0.50** SAD	**0.77** SAD
Remaining capacity (Mode 2)	-0.63	**0.44** SAD	**0.97** SAD	**1.51** SAD	**1.77** SAD

Table 5: Scenario 3 capacity availability (in Mbit/s) in modulation Modes 1 and 2

Mode 1 (FEC ⅔) modulation would not provide a sufficient capacity to allow full resolution services to be broadcast. However, Mode 2 (FEC ¾) modulation would provide sufficient capacity to allow full resolution for the local service, and the national services could be subsampled to ¾ resolution. Mode 1 would be likely to provide sufficient capacity if the local service was subsampled to ¾ resolution and the national services to ⅔.

Subtitling and Audio Description

Mode 1 would be able to support the addition of both subtitling and audio description if the local service was subsampled at ¾ resolution and the national services at ⅔ resolution. In Mode 2 both subtitles and audio description could be supported if the local service was encoded at full resolution and the national services were subsampled at ¾ resolution.

Scenario 4: All services locally statmuxed

Under this scenario, the two national services are encoded at a central headend and distributed via satellite to the local transmission sites. At the local transmission sites, the transport stream containing the two national services is decoded and re-encoded at VBR. The two re-encoded national services are then statistically multiplexed with the single local service (encoded at VBR), which are then modulated for terrestrial transmission.

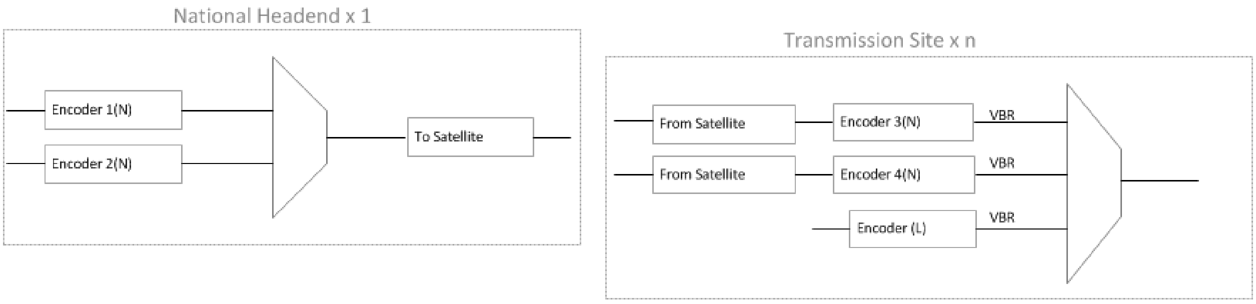

Figure 6: Basic Architecture 4 -National services statmuxed with local service at the transmission site[1]

Under this architecture there is requirement for decoding and re-encoding of the two national services as well as statistical multiplexing these with the local service at the local transmission site. The statistical multiplexing gains assumed under this scenario are the highest of all scenarios, at 12%.

This system architecture may be the costliest of all scenarios. Conversely, it requires the lowest bit rate to represent the 3 services of the architectures considered and therefore it is likely to be the most efficient in terms of overall capacity.

The table below shows the bit rate availability (in Mbit/s) in both modulation modes versus video resolution.

	All services at full res	*Local: full res National: ¾ res*	*All services at ¾ res*	*Local: ¾ res National: ⅔res*	*All services at ⅔ res*
CBR x 3	10.20	9.00	8.40	7.80	7.50
Statmux x 3	8.98	7.92	7.39	6.86	6.60
Total bit rate (incl PSI/SI)	9.58	8.52	7.99	7.46	7.20
Remaining capacity (Mode 1)	-1.53	-0.48	**0.05**	**0.58** SAD	**0.84** SAD
Remaining capacity (Mode 2)	-0.53	**0.53** SAD	**1.06** SAD	**1.58** SAD	**1.85** SAD

Table 6: Scenario 4 capacity availability (in Mbit/s) in modulations Modes 1 and 2

As in previous scenarios, Mode 1 (FEC ⅔) modulation would not provide a sufficient capacity to allow full resolution services to be broadcast. However, in Mode 2 (FEC ¾), there would be likely to be sufficient capacity to allow full resolution for the local service and the national

[1]Another variant of this architecture would be to statmux all 3 services together in the national headend by means of a multiplex manager connected remotely to the local encoder at the transmission site via a bi-directional IP network. The benefit of this option is that it would dispense with the requirement to decode and re-encode the national services and therefore decreasing the amount of equipment at the transmission sites; the drawback is scalability: it would increase the amount of equipment at the national headend proportionally to the number of transmission sites.The addition of IP connectivity and multiplexer manager could impact further the system complexity/cost.

services could be subsampled to ¾ resolution. Mode 1 would be likely to provide sufficient capacity if the local service was subsampled to ¾ resolution and the national services to ⅔.

Subtitling and Audio Description

Mode 1 would be able to support the addition of both subtitles and audio description if the local service was subsampled to ¾ and the national services were subsampled to ⅔ resolution. Mode 2 would be able to support the addition of both subtitling and audio description if the local service was encoded at full resolution and the national services subsampled to ¾ resolution.

6. Abbreviations

b	bit
B	Byte (8 bits)
CBR	Constant Bit-Rate
COFDM	Coded Orthogonal Frequency Division Multiplexing
DSO	Digital switch-over (from analogue TV)
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-S	DVB specification for Satellite Channel Coding and Modulation
DVB-S2	DVB specification for Satellite Channel Coding and Modulation, 2nd Generation
DVB-T	DVB specification for Terrestrial Channel Coding and Modulation
DVB-T2	DVB specification for Terrestrial Channel Coding and Modulation, 2nd Generation
ISO	International Standardization Organization
k	kilo (prefix generally indicating 1,000 but see KB below for use in computing)
KB	KiloByte (2^{10} = 1,024 Bytes)
M	mega (prefix generally indicating 1,000,000 but see MB below for computing)
MB	MegaByte (2^{20} = 1,048,576 Bytes)
MPEG	Moving Pictures Experts Group (ISO/IEC JTC1/SC29/WG11)
OFDM	Orthogonal Frequency Division Multiplexing
PSI	Program Specific Information (in MPEG-2 Transport Stream)
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SDTV	Standard Definition Television
SI	Service Information (defined by DVB)
STB	Set-top-box
UHF	Ultra High Frequency band
VBR	Variable bit-rate

7. References

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