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**Evolving technical architecture for BBC  
public service digital television**

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*Research & Development*  
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### **Abstract**

Major changes to the BBC's Public Service Digital Television (PSDTV) services have taken place during the last eighteen months. These have had a significant impact on the BBC's technical architecture for digital television, with infrastructure in London and national centre in Scotland, Wales and Northern Ireland requiring major change and expansion. This paper outlines the service developments and describes the architectural changes needed to support them under three main categories – statistical multiplexing, time-exclusive services, and enhanced interactive services.

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# **EVOLVING TECHNICAL ARCHITECTURE FOR BBC PUBLIC SERVICE DIGITAL TELEVISION**

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## **ABSTRACT**

Major changes to the BBC's Public Service Digital Television (PSDTV) services have taken place during the last eighteen months. These have had a significant impact on the BBC's technical architecture for digital television, with infrastructure in London and national centre in Scotland, Wales and Northern Ireland requiring major change and expansion. This paper outlines the service developments and describes the architectural changes needed to support them under three main categories – statistical multiplexing, time-exclusive services, and enhanced interactive services.

## **INTRODUCTION**

The BBC began broadcasting its PSDTV services in 1998, and the technical architecture in place at this time was described by Lewis et al (1). By Spring 2001 the BBC was providing a total of six television services on digital satellite (DSAT), digital terrestrial (DTT) and digital cable (DCable) platforms: BBC ONE; BBC TWO; BBC CHOICE; BBC NEWS24; BBC KNOWLEDGE; and BBC PARLIAMENT (as audio and text only on DTT).

Both BBC ONE and BBC TWO carried regional content for viewers in Scotland, Wales and Northern Ireland; and BBC ONE also carried regional content for viewers in different parts of England, although this was available only to DTT and DCable viewers. Regional material is created and inserted locally at regional centres (or national centres for Scotland, Wales and Northern Ireland), requiring local encoding and multiplexing in more than 15 different locations across the UK.

The BBC was also providing interactive 'Digital Text' services on all three platforms, using three different APIs, and was the first broadcaster in the UK to do so.

During 2001 the BBC embarked on a major programme of infrastructure modifications and upgrades that has continued into 2002 and continues today. These changes have supported the introduction of new services and a broadening of the existing categories of service into new areas (for example, launch on new platforms). Subsequent sections describe these changes in terms of the technologies implemented, rather than chronologically, since in practice many of the changes were implemented in parallel.

## **STATISTICAL MULTIPLEXING ON DTT**

One of the major changes to our infrastructure was instigated to allow the BBC complete freedom of scheduling for its new service BBC FOUR. BBC FOUR replaced BBC KNOWLEDGE in early spring 2002 and the programme proposition includes live concerts broadcast at weekends. From its launch BBC KNOWLEDGE had been conveyed on another DTT multiplex managed by SDN but for contractual reasons there were significant periods of the weekend during which bit-rate was not available. Bringing BBC KNOWLEDGE into our own DTT multiplex was thus a prerequisite to launching BBC FOUR.

Unfortunately the BBC multiplex was already full, conveying BBC ONE, BBC TWO, BBC CHOICE, BBC NEWS24 at constant bit-rate (cbr.) together with BBC data services and, as audio-only, BBC PARLIAMENT.

Making space for a fifth linear AV channel implied the use of statistical multiplexing – not an obviously revolutionary step except that the BBC is both a national and regional broadcaster with more than 15 sites across the UK at which regional programmes are inserted. At our sites in Glasgow (Scotland), Belfast (Northern Ireland) and Cardiff (Wales) significant amounts of regional content are inserted into BBC ONE and BBC TWO often by time-shifting national network programmes. At our many smaller regional sites in England it had already been decided for economic reasons only to insert regional content on BBC ONE for digital television.

The bit-rate needed to encode pictures for digital TV to an acceptable quality varies substantially from frame-to-frame, between shots and from one programme to the next. Differences in picture detail, in movement within the scene or even in the techniques used in production mean that, for a given bit-rate, some scenes may look crisp while others suffer from some (or more) of the customary digital effects of 'blocking', loss of detail in faces and on grass or the so-called 'mosquito' noise you sometimes see around the edges of objects in the picture.

Statistical multiplexing is frequently used to reduce the average bit-rate accorded to a service so as to add one or more additional services to the multiplex. This means that we use a somewhat lower average bit-rate than for fixed bit-rate coding. Any instantaneous peak of bit-rate required to code one of the services to a given quality has to be met from corresponding troughs in the bit-rate requirements for the other services in the bundle.

A challenge for the BBC is that we broadcast mixed-genre services, which are competitively scheduled, and our programmes are often visually stimulating with active content that is frequently hard to code. (Several coder manufacturers have been disagreeably surprised by the challenge normal BBC output presents to their products.) There are therefore frequent occasions when several or all of the services in our DTT multiplex are showing 'bit-rate hungry' pictures. Under these conditions the coders will usually get an approximately equal share of the pool and for those times picture quality will be no better than if the services had been coded at the (reduced) average bit-rate.

After prolonged experiments both off-line (using known testing material representative of BBC service propositions) and on-air on DSAT where we already were using statistical multiplexing with the same bundle of services, we established that we could code and statistically multiplex 5 BBC services (ONE, TWO, CHOICE, KNOWLEDGE/FOUR & NEWS24) in one 24 Mbits/s DTT multiplex.

We therefore now distribute over ATM 'sustaining feeds' of lightly-coded ONE, TWO, CHOICE, FOUR and NEWS24 to Cardiff, Belfast and Glasgow where they are decoded, regional content added for ONE and TWO and the five resulting services coded and statistically multiplexed at those places ready for transmission by Crown Castle International in Wales, Northern Ireland and Scotland.

In England we code and statistically multiplex TWO, CHOICE, FOUR & NEWS24 in London leaving space for a cbr-coded ONE. The 'sustaining feed' of lightly-coded ONE is decoded at each regional site, regional content inserted, coded at cbr. and added to the 4:1 stat.mux bundle on site for onward delivery by CCI. This approach obviates the practical problem of running relatively complex statistical multiplexing equipment at sites that have for substantial periods of time little or no technical staff on-site.

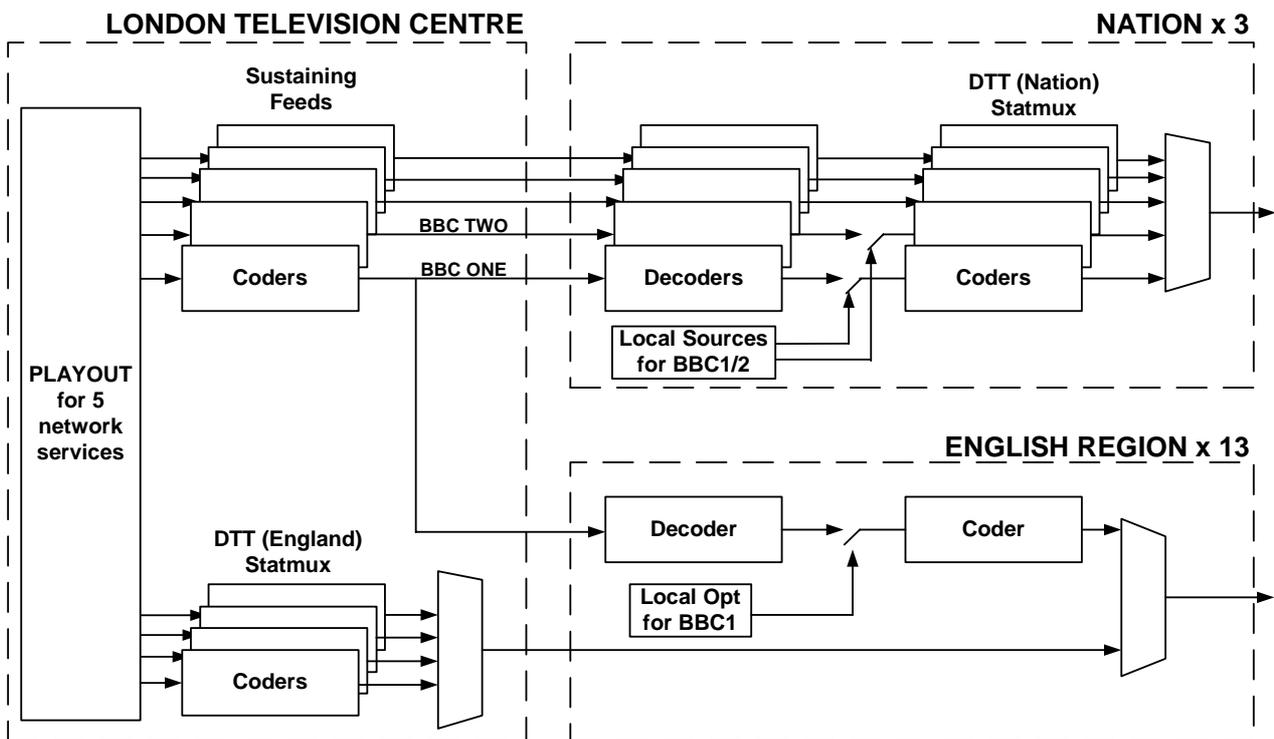


Figure 1 – Simplified architecture for statistical multiplexing on DTT

Some digital cable networks in the UK take DTT as a source for BBC services, using transparent re-multiplexing. The move from constant to variable bit-rate coding had major implications for these operators, as in some instances the original use of cbr had enabled them to divide BBC services between different cable multiplexes. The BBC and the operators therefore had to co-ordinate the changes required to DTT and cable architectures to ensure a smooth transition without loss of service. In practice the changes took place over a period of three weeks, with the re-launch of BBC KNOWLEDGE as a 24x7 service in the BBC's multiplex occurring during a fourth week.

### CBBC AND CBEBBIES – TIME-EXCLUSIVE SERVICES

The BBC has traditionally provided a wide range of programme genres within a limited range of broadcast channels. However with the advent of multi-channel digital television and the associated genre-based Electronic Programme Guides the viewer is often unable to locate the diverse range of BBC content. For example, the BBC transmitted significant amounts of Children's material during the day on BBC CHOICE, but the service itself was classified as an 'Entertainment' channel, and this BBC content would not be found by a viewer looking for channels in the Children's genre.

Channel genres are normally static attributes so the solution to this problem is to provide separate services with the appropriate classification. For most platforms this approach implies different channel numbers for the separate services, but even in the multi-channel world viewers still like to use channel numbers, and broadcasters find them convenient for branding purposes, so this is a benefit rather than a drawback.

There was insufficient capacity available in the BBC's multiplexes simply to provide two extra services. Existing multiplex capacity needed to be shared on a time division basis, particularly on the platforms where the BBC has direct control over the coding and multiplex process – DSAT and DTT. The new channels created were CBBC and CBeebies, sharing capacity with the existing BBC CHOICE and a newly launched BBC FOUR respectively, and

were national channels, available to the whole UK.

Implementing the services required different approaches on different platforms. In the case of DSAT, the platform provides the standard DVB method for turning services on and off, with appropriate behaviour in the STB to inform viewers when a service is off air. In contrast, most UK DTT STBs have no dynamic processing of SI and hence provide no standardised way for managing time-exclusive services. Leaving the viewer with a blank screen when the service was off-air was not acceptable so the BBC adopted a solution using an MHEG application that would boot automatically and present appropriate information when a viewer tuned to a service that was off-air.

Early testing of both the DSAT and DTT chains highlighted a number of issues with equipment which needed to run in a dynamic rather than static configuration. This resulted in the BBC adopting what became known as a 'same packet identifiers (PIDs)' approach. The linear components shared by the time-exclusive services (video, audio etc) are carried using the same PIDs continuously, irrespective of which service is on air at the time, and a particular service is turned 'on' or 'off' by varying the contents of its PMT. This has the advantage of being the least invasive approach from the point of view of the transport stream itself, but the disadvantage is that a failure to change the PMT can result in inappropriate material being made available via the service which should be off-air.

Figure 2 illustrates this approach applied to DTT for two services, BBC FOUR and CBeebies. The composition of the transport stream itself is the same irrespective of which service is on-air, but the composition of the services as determined by their PMTs is determined according to whether they are on or off-air.

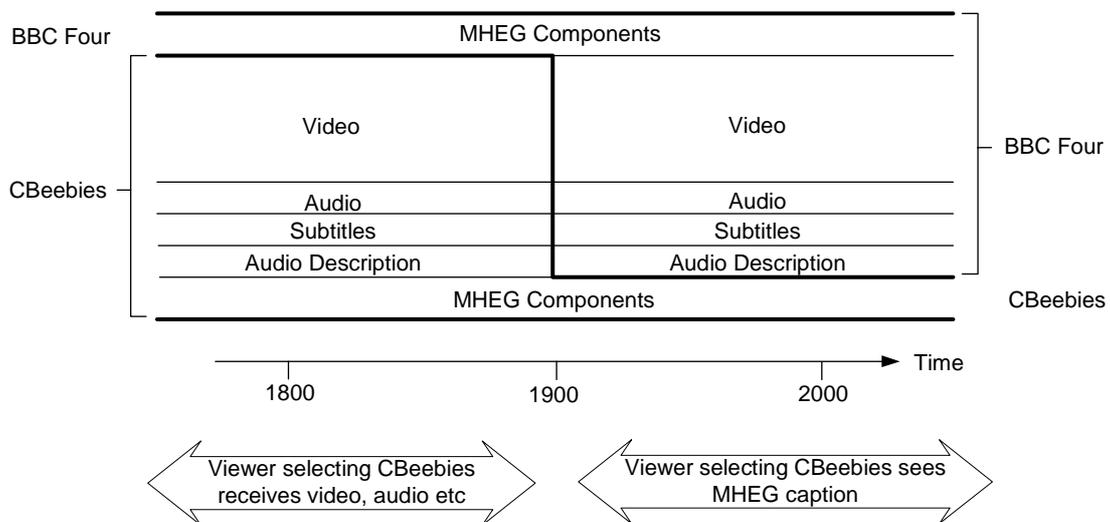


Figure 2 –Evening junction between CBeebies and BBC Four

It was noted earlier that an MHEG application is required to boot to provide a viewer message when a service is off-air. This behaviour is clearly different from that required when a service is on-air, so in addition to declaring a different set of linear components, the PMTs for on and off-air services also contain different data\_broadcast\_id descriptors and carousel\_id descriptors. This effectively defines a different 'boot PID' for a service depending on whether it is on or off-air, and is illustrated in Tables 1 and 2, where an asterisk is used to denote the boot PID for the service.

Service	Video PID	Audio PID	AD PID	Subtitles PID	MHEG PIDs
CBeebies	660	661	662	663	650, 651, 652, 1080*, 1081, 1082
BBC Four					650, 651, 1090, 1091, 1092*

Table 1: Service composition when CBeebies carries programmes

Service	Video PID	Audio PID	AD PID	Subtitles PID	MHEG PIDs
CBeebies					650, 651, 1080, 1081, 1082*
BBC Four	660	661	662	663	650, 651, 652, 1090*, 1091, 1092

Table 2: Service composition when BBC FOUR carries programmes

It is worth noting in passing that the current UK profile of MHEG (V1.05) only supports the dismounting and remounting of the carousel at the change of the boot descriptors. Version 1.06 will support new lifecycle application functionality, that will be better able to support service switching.

The configuration of the BBC's DSAT services is controlled by a final multiplexer, located at Television Centre in London, which is under the control of systems owned and run by BSkyB. In order to schedule new service configurations the BSkyB systems need to be populated with suitable schedules.

For DTT, the situation has been complicated by the introduction of statistical multiplexing, and the consequent creation of separate statistically coded multiplexes in each national centre in addition to Television Centre. In effect there are now four different versions of all services to be controlled, and this has meant that the control over which services are on-air can no longer be achieved at one central location.

The BBC's EPG system – SID – has been extensively updated to provide facilities to manage time exclusive services. The graphical user interface has been updated to provide facilities for enforcing service schedules against templates held in the database. This prevents EPG staff from inadvertently turning services off. The schedule distribution system has been enhanced to distribute schedules to the nations DTT coding and multiplex centres over a wide area network. The functionality already existed to drive the BSkyB interface.

All systems need to have the same time references. To achieve this network time protocol (NTP) was adopted as the standard. GPS receivers in four locations provide an accurate and resilient source of time.

The decision was taken that integrity of switching was more important than flexible service airtime. The system implemented allows for easy re-configuration of service times but does not allow services to over-run their allotted airtime. This also has the benefit of removing any element of real-time control over the service switch times in most cases. However this separation was not possible for London DTT as the system is also used to generate SI for broadcast. With the current mix of systems the BBC supports it was not possible to separate out completely multiplex control from SI generation, although we wish to achieve this separation in future architectures.

The BBC's internal transport stream monitoring system has been upgraded to monitor which services are on air and compare this against pre-defined templates. Any deviation from the templates results in alarms being raised. The lack of any standardised method for control over the final service configuration has meant that each stream is managed in a different

way and consequently has different failure mechanisms.

As with the introduction of statistical multiplexing, careful co-ordination was required with cable operators to ensure a smooth introduction of the new services on digital cable networks. This was largely successful, with only minor teething troubles on some networks.

The BBC's introduction of time-exclusive services, across three platforms and within a regionalised coding and multiplexing architecture, was achieved during a short overnight period in February 2002 without disrupting the schedules of the 24-hour services that had run until 0200 that morning. CBeebies and CBBC were on-air from 0530 and carried programmes from 0600 and 0700 respectively.

## **ENHANCED INTERACTIVE SERVICES**

Interactive television is by no means a mature market. Looking specifically at the UK, each of the three main networks has chosen different technologies to support interactive services and each has deployed its chosen technology to its own timetable. For the BBC in its role as a content provider this has meant that the development of both services and the necessary supporting infrastructure has taken place as three separate activities, i.e. on a network by network basis.

This diversity creates a number of issues, not least that for a particular proposition, a separate version of the service needs to be created for each network. Essentially three applications need to be authored and broadcast - MHEG for DTT, Liberate for DCable and OpenTV for DSAT. This is made more complex by the fact that the functional capabilities of each network are not identical, making the translation of a proposition to the three targets less than straightforward.

In the UK, interactive services on DTT and DSAT are essentially broadcast services, with the interactive applications delivered in the transport stream along with the linear content. This applies equally to Enhanced TV (interactive services that have a direct relationship with the linear content) and to more general services such as magazine services. The different characteristics of the DCable platform have resulted in the use of a hybrid model for delivery, with content deliverable 'out-of-band' in response to a request from a specific user, or broadcast 'in-band' along with the linear content. Out-of-band delivery offers a one-to-one connection between the viewer and content provider. Content delivered by this means is essentially independent of broadcast services and the service is frequently referred to as 'TV-Internet'. In contrast, in-band delivery is essential for developing interactive services closely associated with the linear content (ETV).

Technical architecture for the BBC's interactive services is illustrated in Figure 3, showing content aggregation, application and service build, playout and distribution. Interactive services using the DTT and DSAT architectures have been operational since 1999 and 2001 respectively. The 'TV Internet' services on DCable, using the out-of-band path, were introduced in 2000, and 'ETV' services using the in-band path are being introduced during 2002.

### **Multi-stream and other ETV services**

The BBC had introduced a Digital Text service on DSAT in the spring of 2001, and introduced its first multi-stream interactive services during the summer of 2001. This type of service uses an interactive application to allow the viewer to select from a choice of audio-visual streams. The first example of this was during the Wimbledon tennis tournament, and allowed a viewer watching coverage of the tournament on a channel such as BBC TWO to choose between five different matches. To deliver the alternative streams required additional satellite capacity (i.e. a third transponder), an additional coding and multiplexing

system and a new 'Multi-Stream Area' (MSA) in Television Centre to control and playout the additional streams.

During the summer and autumn of 2001 the BBC provided multi-stream coverage of a number of other events on DSAT. At this time it was not possible to provide similar propositions on DTT and DCABLE, but these platforms also carried enhancements associated with such events in the form of rich magazine content.

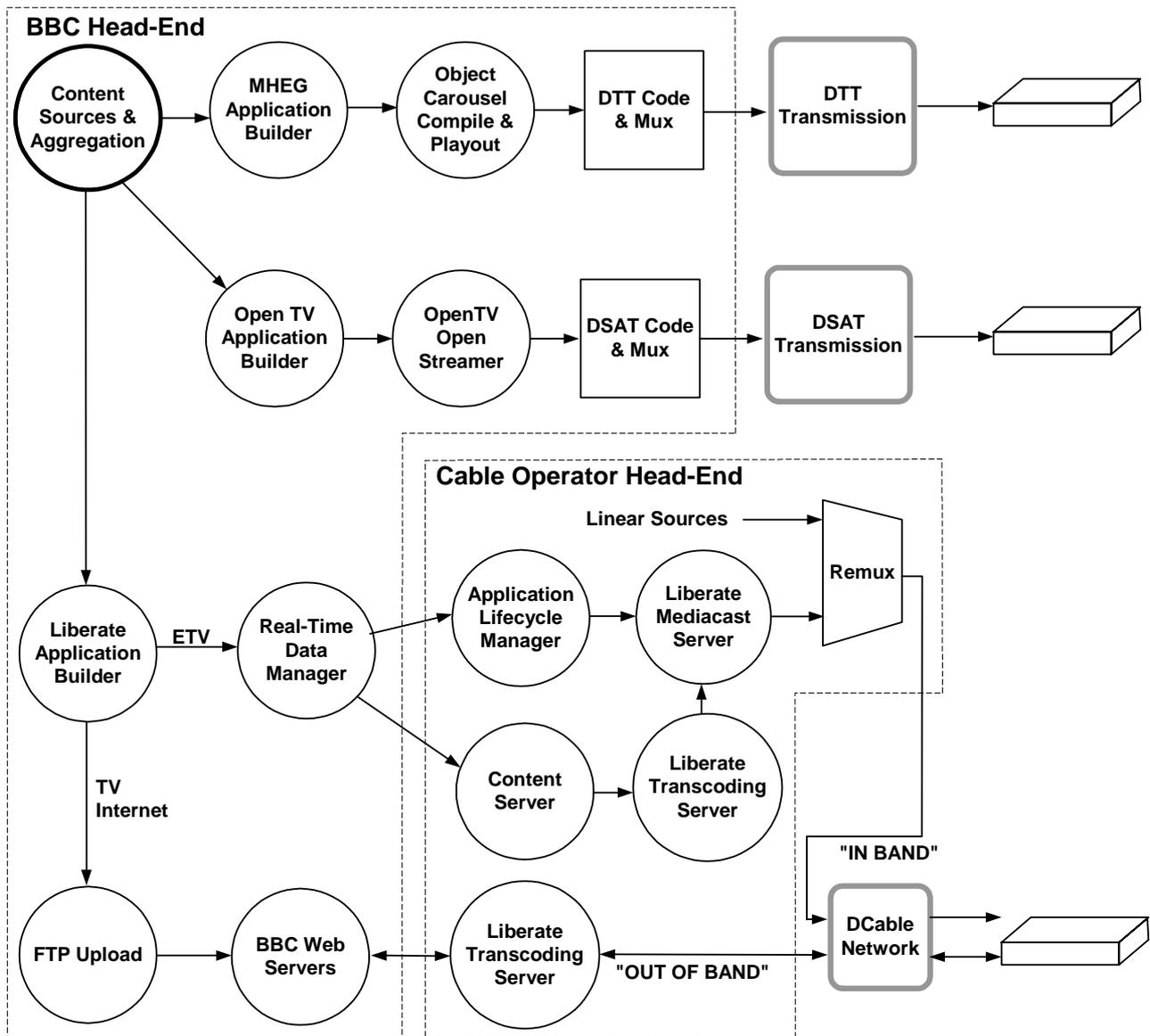


Figure 3 – Simplified technical architecture for BBC interactive services

### Additional DSAT services introduced in 2002

In January 2002 the BBC began to exploit its additional capacity on satellite on a more regular basis by providing access to selected English regional news programmes via an interactive application. On BBC ONE the early evening news programme runs from 1800 to 1900, roughly half of this time being devoted to regional news. Selected regional bulletins are fed back to Television Centre in London, using existing 34 Mb/s contribution circuits, and are then passed through the MSA to feed the multi-stream coding and multiplexing. At 1800 an icon appears on the BBC ONE service seen by digital satellite viewers in England, who can then select between news programmes from five different regions (originating from

Birmingham, Manchester or Leeds for example).

The BBC has recently acquired further satellite capacity, which will be used to extend the availability of English regional news services in due course. However, there are insufficient 34 Mb/s contribution circuits to scale the existing architecture to accommodate the additional regions, and a new architecture is under development.

### **Multi-stream enhancements on DTT and DCable in 2002**

Lack of available capacity on the DTT and DCable platforms meant that the BBC was unable to offer multi-stream enhancements during 2001. However, at the time of writing plans are well advanced for providing these services during the summer of 2002.

In the case of DTT, the BBC intends to use leased capacity on another multiplex to carry the additional streams. The multiplex operator will encode the multi-streams at its head-end, using SDI feeds from Television Centre. The interactive application controlling access to the streams is played out from Television Centre and fed to the head-end as a transport stream. This application has been authored entirely by the BBC and, as for the DSAT applications that preceded it, is entered from one of the BBC's core channels carried within the BBC multiplex.

In the case of DCable, the multi-stream proposition varies between networks, but in each case the BBC has worked closely with cable operators and their API vendors to develop the applications to support the multi-stream proposition.

### **CONCLUSION**

Recent months have seen an unprecedented rate of change to BBC television services on digital platforms, enabled by an equally unprecedented series of developments to the supporting technical infrastructure. Further service developments are foreseen in the coming months and will result in the continued evolution of the BBC's technical architecture for public service digital television.

### **REFERENCES**

1. Lewis, A., Ely, S., Fry, N., King, D., 1998. [Digitising Auntie](#). Proceedings of the International Broadcasting Convention. pp. 272 to 277.

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