The Service Multiplex

By Gary Tonge

One of the goals of the current European work on digital television broadcasting is to achieve as much commonality as is practicable between system specifications for terrestrial, satellite, and cable applications. It is already generally accepted that the MPEG-2 standard should provide the basis for common source coding across these applications. Modulation and channel coding, on the other hand, are likely to be application-specific because of the very different properties of terrestrial, satellite, and cable channels. Lying somewhere in the middle is the area of multiplexing. The prospect for a common approach to multiplexing across different media, and indeed between different regions of the world, has excited widespread interest. But what exactly is multiplexing, what features would a common system need to deliver to broadcasters and consumers, and is a common approach to multiplexing feasible?

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This article is written as a general overview, and not from the perspective of a technical expert familiar in detail with the terminology and specifications within the ISO/IEC MPEG (Moving Picture Experts Group) activity. The aim is to demystify what has been a complex subject, while hopefully not misrepresenting the detailed and sophisticated technical work that is taking place.

What is Multiplexing?

The concept of multiplexing is in essence quite straightforward. It is the action of combining different pieces of information for carrying within a particular communication resource. The NTSC, PAL, or SECAM transmission systems, for example, represent a multiplex of luminance, color difference, and sound signals. The method used is called frequency division multiplexing. Another definition of multiplexing when considered in the digital domain is the assembling of several component bit streams into one, for the purpose of processing and transporting the different components in a coherent manner.

In terms of digital television transmission systems, two layers of multiplexing can be considered as shown in Fig. 1. One is the "service" or "program" multiplex, which combines vision, sound, and ancillary data signals for a given service or program. The other is the "ensemble" multiplex, which combines different services or programs with any further ancillary data that is necessary, into a single ensemble for transmission. It is sometimes helpful to consider a digital television system in terms of the ISO Open System Interconnection (OSI) "layer" model. In this context it is possible to consider the service multiplex as being at layer 4, and the ensemble multiplex at layer 3, as illustrated in Table 1. Alternative interpretations of the OSI layer model are possible, including one which considers both types of multiplex as being at layer 4, with broadcasting applications having no layer 3 at all. In either case, however, the layer model is helpful in illustrating the type of function fulfilled by multiplexing and where it fits in with other functions in the broadcast chain.

The simple model of a two-level multiplex — one putting together the different elements of a service, the other putting together different services into a single channel — does not, unfortunately, translate exactly into the

Table 1 — An Example Description of a Digital TV System According to the OSI Layer Model

Layer	Description	Example Feature or Function
7. Application	Practical use of the system	Number and type of services offered
6. Presentation	Conversion for	Video scanning document
5. Session	data selection and access to information	Program selection
4. Transport	Grouping of data	Service multiplex
3. Network	Logical channel	Ensemble multiplex
2. Data link	Format of the transmitted signal	Transmission frames
1. Physical	Physical transmission	Modulation and transmission

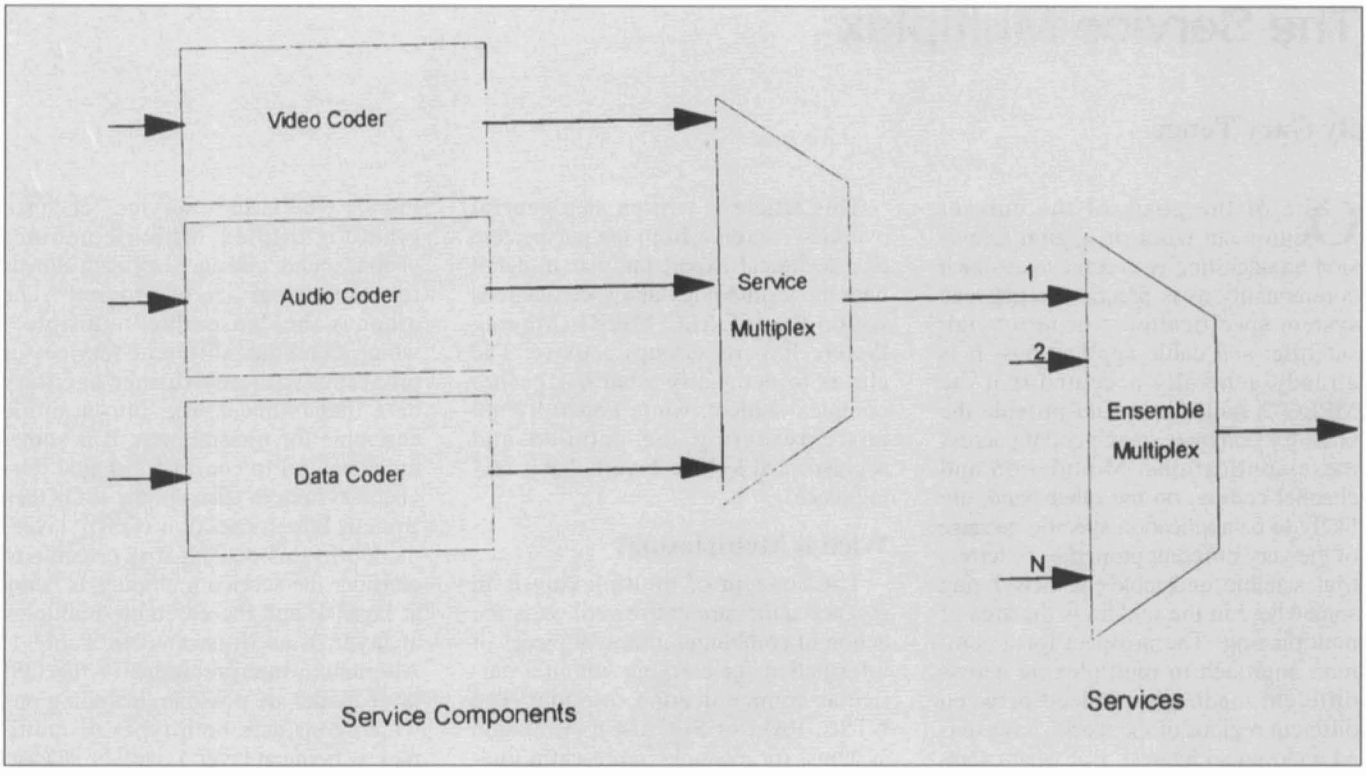

Figure 1. The service and ensemble multiplexes.

terminology used in MPEG. In the current work on the MPEG-2 standard, the task of multiplexing the video, audio, and other data streams for storage or transmission is addressed by the "systems standard" or the "systems layer." The standard does not specify the architecture or implementation of multiplexers or demultiplexers, it merely specifies the properties of the appropriate data streams. In MPEG-2, both the service multiplex and the ensemble multiplex described above are considered together in the combining of various video, audio, and data streams into a single program stream or transport stream, depending on the intended application. In MPEG parlance, therefore, the output of the two multiplexing operations shown in Fig. 1 will be one of these streams.

The program stream is intended for error-free environments and all the input streams need to be synchronized, for example, being derived from only one program source. The transport stream is the one relevant to broadcasting, since it is intended for environments where errors are likely, and it allows for different input programs not to be synchronized. The two types of stream can coexist, in the sense that one or more program streams can be converted into a transport stream if that is appropriate. The transport stream is defined in terms of packets which are of a fixed length (188 bytes), although typically the packets of video, audio, or data information that are repackaged to become the transport stream are not of fixed length, and are longer than the transport packets. The two types of packets are aligned, however, so that the start of a video or audio packet coincides with that of a transport packet. The transport packet structure does not relate directly to the logical structure of any of the input data; for example, it is not related to the line or frame structure of an input picture. Transport packets begin with a 4-byte prefix, which contains a packet identifier. The transport stream as a whole contains a "program association table" and a "program map table." From these tables the Service Identification information for a particular program can be found, and the necessary information to demultiplex all the services present in the transport stream can be obtained. More than 8,000 different input video, audio, or data streams can be combined in an MPEG-2 transport stream.

Broadcasters' Requirements for a Common Multiplex System

The EBU has drawn up a comprehensive list of requirements for a common multiplex system that can be used for digital television broadcasting and has examined a number of candidate systems in the light of these requirements. The requirements considered to be "essential" were as follows.

General Requirements

The multiplex system should:

- Provide maximum commonality for different transmission media, particularly terrestrial, satellite (BSS, FSS), cable, and B-ISDN.
- Support different configurations of services and service components, including television, sound, and data (related and unrelated) with their associated bit rates.
- Support dynamic and flexible reconfigurations of the multiplex.
- Permit flexible service information (SI) for all configurations of services and service components.
- Provide for high efficiency and ruggedness in the presence of undetected transmission errors.
- Provide rugged end-to-end syn-

chronization for synchronous, plesiosynchronous, and asynchronous sources.

- Lend itself to implementation of appropriate conditional access systems applied either to the components of the service, to the service, or to multiple services of the entire ensemble.

Service Components Related Requirements

The multiplex system should:

- Be transparent to a limited number of different source-coded signals and associated bit rates.
- Permit adequate synchronization of related service components.
- Support mechanisms for linking of service components, services and ensembles, within or between different services, or ensembles.
- Allow conditional access to be applied on each individual service component.

Transmission Related Requirements

The multiplex system should:

- Allow for easy transfer, involving minimum processing required between different transmission media, in particular from satellite to cable/terrestrial retransmission.
- Allow extraction and insertion of services and service components at the multiplex level.
- Provide sufficient capacity to accommodate information on the configuration/reconfiguration of services and service components (i.e., service information) to the user.
- Provide a constant, user-defined bit-rate service and ensemble multiplex bit stream for a given transmission medium.

End-User Related Requirements

The multiplex system should:

- Allow common receiver processing to enable usage in different transmission media.
- Allow a simple demultiplexing process to be applied at the receiver; in particular, it should be possible to operate on the relevant part of the data without having to decode the whole multiplex.
- Allow easy service selection according to service source, program type, program language, etc.

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The preliminary conclusion of the EBU analysis is that the multiplexing structure being developed within the MPEG-2 system meet all of these important requirements. However, in the case of the fifth general requirement (to provide for high efficiency and ruggedness in the presence of undetected transmission errors) it is considered that an extra layer of "adapting" the MPEG transport stream is required in interfacing with a modulation and transmission system for broadcast channels. This adaptation layer (corresponding to layer 2 or the data-link layer in the OSI model of Table 1) could also be used to apply differential error protection to different program elements in a "hierarchical" or "multilevel" system (which might be designed, for example, to provide HDTV quality in good reception conditions, degrading to standard-definition quality under poorer conditions). The adaptation would ideally be application-specific, being tailored to the error properties of the terrestrial, satellite, or cable channel. The adaptation would be applied, however, outside of the framework of the MPEG standard. The MPEG-2 standard therefore promises to be successful in forming the basis for a common multiplexing standard across different transmission media (terrestrial, satellite, and cable), as well as providing the common basis for source coding. It would be possible to design a more efficient multiplex (in terms of one which carries less overhead for headers, description, and synchronization information) for one particular application, but the prospect of a common system is thought to be worthy of sacrificing any such small efficiency gains.

Urgent work is progressing in Europe aimed at producing a draft specification for a digital standard (based on MPEG-2) for satellite and cable broadcasting. The target for a terrestrial specification is the end of 1995. For each of the media it is expected that a repackaging of MPEG transport packets into a frame-based transmission system will be required for increased robustness against channel errors. A multilayer, or hierarchical approach, is also being considered for the terrestrial application.

Conclusion

Future digital television broadcasting systems promise to be very flexible. The same channel might be used at different times of the day for, say, one HDTV service, 2 extended-definition services, 4 standard-definition services, 16 lower-definition services, or some combination of these possibilities. Data services of various types are likely to be included, as well as data directly connected with the TV services such as conditional access or subtitling information. Coping with this flexibility requires a powerful multiplexing system. The emerging MPEG-2 standard seems to provide this. Perhaps the major challenge in the implementation of these flexible services will not be the design and implementation of the multiplex, but the creation of a user friendly receiver in which program and feature selection is simple and straightforward for the viewer.