Digital Audio and Internet Radio Broadcasting Systems under a QoS Perspective

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Abstract: - Examination of the Quality of Service (QoS) at the end-user level of multimedia broadcasting systems is necessary in order to retain the overall performance and the user's satisfaction level from the provided services, by revealing the possible weaknesses of the systems' specifications. Accordingly we examine Digital Audio Broadcasting (DAB) system's characteristics at the services level, with a view to propose some extensions to the DAB system and to examine QoS specifications for Internet radio broadcasting.

Keywords: - Digital Audio Broadcasting, DAB, Internet radio, Quality of Service, QoS, Multimedia broadcasting, Multimedia services, Communication engineering.

1 Introduction

Several standards have been proposed, tested and established worldwide, in order to replace analog broadcasting systems with digital ones offering enhanced multimedia-signal broadcasting. The Digital Audio Broadcasting system is a well promising, spectrum- and power- efficient audio and data broadcasting system [1]-[3]. It uses advanced digital techniques to remove redundant and irrelevant information from the audio source signal, and also applies controlled redundancy to the transmitted signal to provide strong error protection.

The DAB system delivers multimedia communications involving digital audio and video. Such services impose certain high quality requirements compared to the poor QoS of classical radio broadcasting systems. These QoS requirements are met by the use of certain channel encoding techniques, and the exploitation of the MPEG family encoding algorithms [4].

Meeting QoS guarantees in distributed multimedia systems, is fundamentally an end-to-end (from application to application) issue [5]. QoS assurances should apply to the complete flow of media from the remote server across the network to the delivery points. For applications relying on the transfer of multimedia and continuous media flows, it is essential that QoS is configurable, predictable and maintainable system-wide, including the end-system devices, communication subsystems and networks.

It is the objective of the present paper to provide an overview of the procedures required for achieving maximum QoS guarantees in digital audio broadcasting systems. Specifically, Section 2 introduces a novel hybrid platform capable of broadcasting signals according to multiple standards, so that the QoS specifications and requirements can be examined in Section 3.

2 A DAB and Internet Radio Hybrid System

One very important form of digital radio broadcasting -even if it seems still underestimated- is the one that is going to be vastly used in the future: internet radio. It is a fact that radio became popular because of its mobile nature -and so far mobile Internet has limited capabilities- but it is certain that in the years to come most light-weight electronic devices will have internet access. The most important representatives of this kind of electronic devices are the new generation mobile phones. Internet radio poses a significant threat to the new, well-defined media standards as DAB.

Two matters have given rise to much concern. The first one is the difficulty of achieving a smooth replacement of the analog FM broadcasting systems with the new digital ones. The second matter has not been widely discussed, but is concerned with the effect that the vast explosion of Internet radio broadcasting will have on the establishment of Digital Radio Broadcasting. Recently there has been wide interest in having the Internet serve as next-generation replacement for existing, long established communications media, as the telephone system, radio and TV. In all three cases, the basic functionality of these communications systems has not changed in several decades; addition of extra features is difficult. Digital Audio Broadcasting simply replaces the transmission infrastructure, without actually offering significant new services. It does not also change the fundamental issue that only a very small number of stations can transmit at any given time, at a specific region.

On the other hand as the Internet expands vastly, more and more radio stations choose to broadcast this way. Special internet broadcasting systems for radio stations have been used, but most of them either ignore the analogue aspect of broadcasting, or just encode the analogue signal into a low-quality digital broadcasted one.

In this Section we describe all the subsystems of a novel radio platform [6]-[7], which is especially designed to operate under all forms of broadcasting exploiting each system's special abilities, i.e., the ease and simplicity of FM radio, the enhanced multimedia capabilities of DAB, and the full bi-directional, user-orientated philosophy of the Internet radio.

In order for a radio station to broadcast in both systems (FM and DAB), while the transition is still being made, new generations of hybrid radio systems were designed and implemented. The usual drawback of the existing solutions is the fact that they usually neglect to unify all existing digital media technologies. This means that the proposed systems usually lack full exploitation of the advantages of the digital era in media technologies, and are not compatible with other existing or future broadcasting technologies. These drawbacks in most existing analogue and digital radio broadcasting systems led us to design a new radio broadcasting platform, which is capable of transmitting audio or multimedia signals using every technology available (FM, AM, MW, Internet, DAB). The implemented system consists of software libraries and executable software components, created with various programming tools like Delphi, Visual Basic and C++. The software libraries contain application-independent components, such as the MPEG encoder/decoder or the COFDM multiplexer/ demultiplexer. These modules are described in the following subsection. The software executables implement the modules embedded into the subsystems described and use the software libraries in order to perform all tasks regarding handling, storing and broadcasting the multimedia signals. The platform was designed to work under all operating systems, but its prototype version is currently working under Microsoft Windows NT, 2000, or XP editions.

2.1 Software modules

The parts consisting the radio broadcasting platform, are implemented in three autonomous, but cooperatively working, software applications. As it is shown in Fig. 1, these applications are:

- A Database Management Application that handles the audio signals, and supports all relevant functions such as encoding of audio samples, association of multimedia objects to audio signals, controlling RDS and DAB enhanced services, etc.
- A Server Application that keeps the audio signals and associated multimedia objects always available for broadcasting.
- A Client Application for each remote listener, which receives the broadcasted signal.

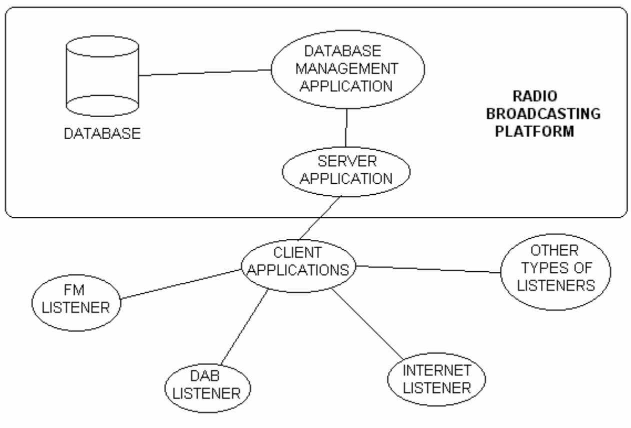

Figure 1. Software modules.

Each way of broadcasting demands its own client application for receiving, decoding and presenting the signal to the user/listener. The FM and DAB receivers include this particular software in their own embedded software applications. In the case of Internet listeners, a special client application was designed and implemented, in order for the user to connect with the server and start receiving the audio signal and the associated multimedia objects from the broadcaster.

The system is designed in such a way that its database contents and handling capabilities can be located at different locations. The Server Application is the one that has to be located at the radio station, which fetches the audio samples and the multimedia objects associated with them from the locations indicated by the Database Management Application. In this way distribution of the applications working together is accomplished, and thus restrictions regarding the location of the system and of the users working with it are eliminated.

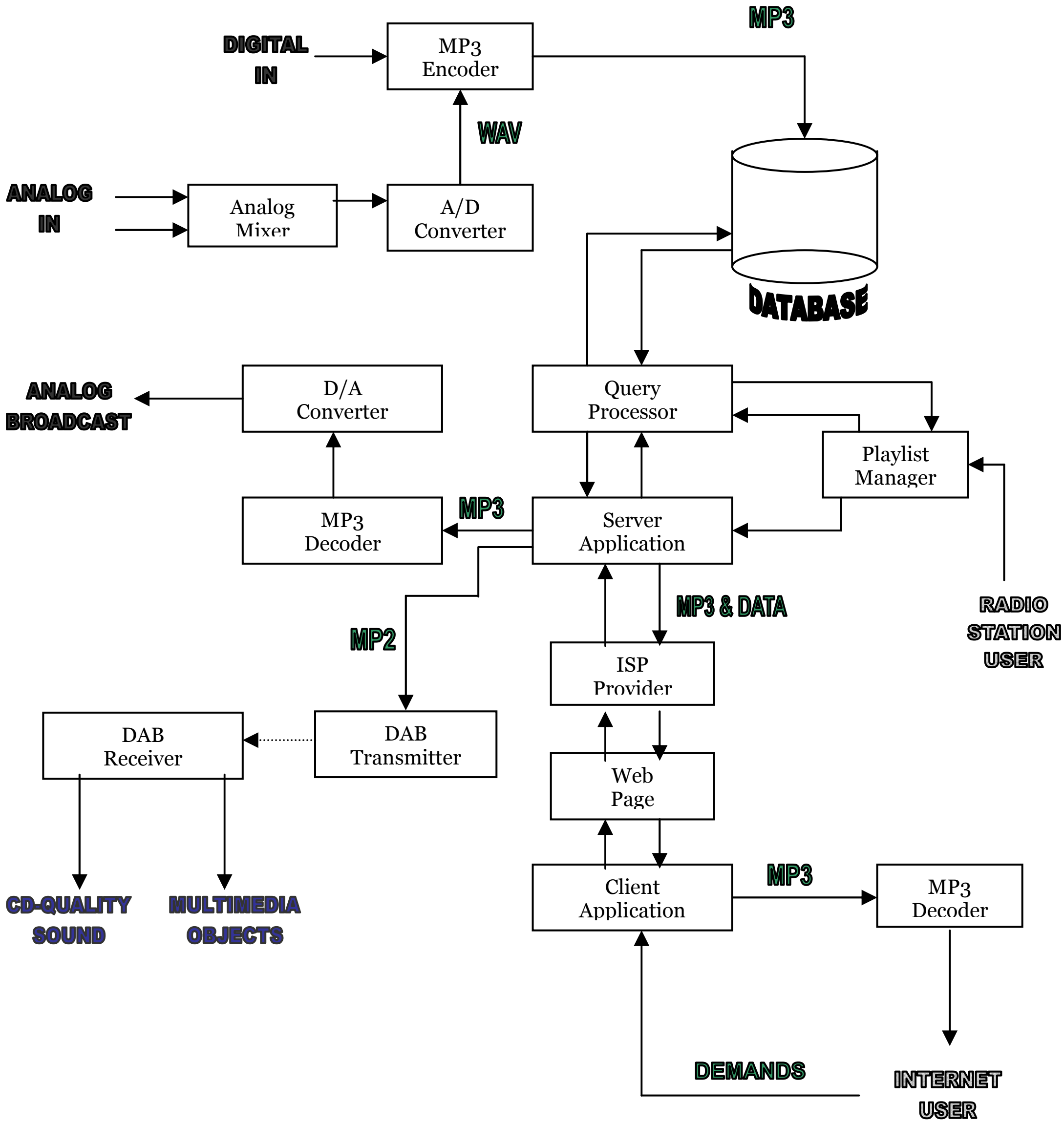

Figure 2. General block diagram of the system's architectural structure.

2.2 System Architecture

In order to describe the way which the radio broadcasting platform works, we have to describe the functionality of every subsystem involved in Fig. 2. The analogue signal is first sampled and then encoded, in order to be stored into the audio digital samples database. Digital audio signals, unlike analogue signals, are just captured and then encoded before being stored. Even though the audio encoding used is the MPEG Audio Layer II, the system is designed in such a way that it can use any user-provided encoding algorithm, which replaces or works in parallel with the MPEG compression. In the case of using two or more encoding procedures, the audio samples should be stored into different databases according to the type of compression used. Along with the audio samples, data associated with them are stored in the database. Part of the data identifies certain properties of each audio sample (i.e., time length, location of storage, encoding format, etc.), but the rest are information data to be transmitted (e.g. text through RDS, images through DAB, video samples through Internet). Data are encoded according to the standards imposed by the nature of the transmission medium. As the audio samples and the data associated to it enter the database, the user of the Database Management Application has to create a programmed audio samples playlist to be broadcasted.

The encoded signal is driven to a server application (embedded into –and not to be confused with- the Server Application mentioned in the previous paragraph). This application is permanently connected to an Internet Services Provider, in order to broadcast the signal. To be more precise, in this case the signal is not literally broadcasted, but made "available" to be received from each Internet user that connects to the server and requests it. The Internet user has to visit the web page containing the appropriate links and install a client application that contains the decoders for the audio and multimedia objects multiplexed signal. This application is responsible for maintaining the connection to the server, and for presenting the signal to the user with the minimum rate of faults.

After the encoded signal and the data associated to the audio samples leave the Management sub-system, the DAB signal is created. Time interleaving improves the ruggedness of data transmission in a changing environment and imposes a 384 ms transmission delay, according to the standards imposed by the European Telecommunication Standard Institute. The encoded and interleaved data are fed to the Main Service Multiplexer (MUX) where, at every 24 ms, the data are transformed into a multiplexed frame. The combined bit-stream output from the multiplexer is the point where all synchronised data from all the program services are brought together, in order to be modulated and then be transmitted.

3 A QoS Perspective

Since, meeting QoS guarantees is an end-to-end issue, we should examine how QoS specifications apply in each component of a DAB network. As it is stated in previous works in QoS guarantees in multimedia communications [8], there are three guarantees' levels:

- Hard or deterministic guarantee, when user-specified QoS should be met 100%,
- Soft or statistical guarantee, when user-specified QoS should be met up to a specified percentage (appropriate for continuous media, which normally do not need 100% accuracy in playback),
- Best effort, when no guarantee is provided and the application is executed with whatever resources are available.

At the distributed system platform level, QoS specification is rather application-oriented than system-oriented. Considerations such as the strict synchronization of multiple related audio and video flows, the rate and burst size of flows, or the details of thread scheduling in the end-system should all be kept in the lower level. QoS specification is therefore declarative in nature; applications specify what is required rather than how that is to be achieved by underlying QoS mechanisms. QoS specification encompasses [8], but is not limited to the following:

- Flow performance specification, which characterizes the user's flow performance requirements.
- Level of service, which specifies the degree of end-to-end resource commitment required.
- QoS management's policy, which captures the degree of QoS adaptation that the flow can tolerate and the scaling actions to be taken in the event of violations in the contracted QoS.
- Cost of service, which specifies the price the user is willing to incur for the level of service.
- Flow synchronization specification, which characterizes the degree of synchronization between multiple related flows.

A DAB network is consisted of three key elements: the broadcasting station, the communication medium or channel, and the receiving sub-stations. By default, the latter two elements of a DAB network are fully specified, as far as QoS requirements are concerned. So, after the implementation of the three basic techniques used by DAB (data encoding, channel encoding and error correction in the receiver), the DAB system meets even the most hard or deterministic guarantees:

- By encoding the signal to be transmitted, the transmitter achieves the three following goals. First, the drastic limitation of the quantity of information to be send through the channel, with a little effect on the quality of the transmitted signal. Second, the graceful quality degradation of the multimedia data encoded, that is the prioritization of the encoding layers that contain data essential to produce basic acceptable playout (audio/video) quality [8]. Third, the encapsulation of basic error detection schemes in the transmitted signal, in order to recognize the fault.

- By employing Coded Orthogonal Frequency Division Multiplexing (COFDM), the 2.3 million bits of the multiplexed signal are spread out in time and across 1,536 distinct frequencies within the 1.5 MHz band, so that even if some frequencies are affected by interference, the receiver will still be able to recover the original signal.
- By error protection techniques, as the parallel transmission scheme, the receiver reverses the multiplexing and audio encoding applied during transmission, eliminating any transmission errors.

It is clear that since the QoS requirements for a DAB network are end-to-end specified, the DAB network should be properly operating meeting all QoS specifications, as the ones described at the beginning of this Section. As we can conclude, though, by a closer study of these specifications, a DAB network is not only consisted by the broadcasting, channel and receiving components. In order to assure QoS guarantees, we must examine the specifications stated above in the signal creation and management procedures of a DAB network. That is, the full procedures of creating, storing, and queuing audio samples (along with extra data associated to them) in order for a radio program to be created and broadcasted.

3.1 QoS Requirements

In order to examine QoS specifications for a real-world implementation of a DAB system, we choose the platform described in Section 2. This platform provides the radio station user with an advanced user interface that encapsulates all the functions and control mechanisms offered by DAB. The main QoS specifications to be met by DAB, as a multimedia communication system, will be closely examined in the following paragraphs.

3.1.1 Flow performance requirements

The ability to guarantee traffic throughput rates, delay, jitter and loss rates is particularly important for multimedia communications. QoS frameworks must have prior knowledge of the expected traffic characteristics associated with each flow before resource guarantees can be met. Since the DAB signal has a pre-defined bandwidth of 1.5 MHz, and a multicast nature (that is all the receivers "listen" to the same channel), the throughput rates can be a-priori calculated, and the signal is limited within this certain bandwidth. In an Internet radio application, the performance rates differ, according to the network conditions (Table I). Delay, jitter and loss rates can be statistically described, since the nature of the carrying medium is already known. All these interferences are avoided by the error protection schemes used by DAB.

3.1.2 Level of service

While the flow performance specification permits the user to express the required performance metrics in a quantitative manner, level of service allows these requirements to be refined in a qualitative way to allow a distinction to be made between hard and soft performance guarantees. In the case of the DAB platform under examination, the level of service is strictly defined to be hard or deterministic. Under certain circumstances though, as the time period of transition from FM broadcasting system to DAB, this level of service can be defined as soft or statistical. If alternative sources of a chosen program service are available and an original digital service becomes untenable, then linking data are used to identify an alternative (e.g. an FM service) and switch to it. In such a case, the DAB/FM receiver will switch back to the DAB service as soon as reception is possible. This is a particularly important feature at the start of DAB services, in order to maintain an acceptable level of QoS guarantees.

3.1.3 Management policy

For example, audio and video flows can be represented at the playout device with minimal perceptual distortion, by trading off temporal and spatial quality to available bandwidth, or manipulating the playout time of continuous media in response to variation in delay. The DAB platform under examination offers all management and control services to the radio station user, via a highly sophisticated but also user-friendly interface, that supports all the available management policy choices of the user. In this way, the user can reduce the quality of the concurrently transmitted sound signals, in order to add a multimedia session into the signal, or just demand highest quality possible and let the system manage the usage of the available bandwidth.

3.1.4 Cost of service

Cost of service is a very important factor when considering QoS specification. The implementation of the DAB platform as a software orientated information system, leads to no extra cost of service involved in QoS specification. Therefore, there is no reason for the user to select anything other than maximum level of service. There is always though the ability to select the desirable level of services to be provided to the listeners of the radio station.

3.1.5 Flow synchronization specification

A distinctive example is simultaneously recorded video perspectives that have to be played in precise frame-by-frame synchrony, so that relevant features may be simultaneously observed. On the other hand, in the case of DAB the main information channel is only auditory, and video (or other multimedia objects such as plain text or images) is only used to enhance the broadcast signal, so there is no need for ultimate synchronization.

Table I: Typical performance values for different channel bandwidths.

Type	Channel Bandwidth	Typical Quality	8-bit Mono	16-bit Mono	8-bit Stereo	16-bit Stereo
Modem 14.4	14.4 Kbps	12-14 Kbps	12 KHz	-	-	-
Modem 28,8	28.8 Kbps	25-28 Kbps	24 KHz	12 KHz	12 KHz	-
Modem 33.6	33.6 Kbps	30-32 Kbps	32 KHz	16 KHz	16 KHz	8 KHz
Modem 56K	56 Kbps	50-54 Kbps	48 KHz	24 KHz	24 KHz	12 KHz
ISDN-56K	56 Kbps	52-56 Kbps	48 KHz	24 KHz	24 KHz	12 KHz
ISDN-128K	128 Kbps	125-128 Kbps	48 KHz	48 KHz	48 KHz	32 KHz
Cable	2 Mbps	1.8-2 Mbps	48 KHz	48 KHz	48 KHz	48 KHz

4 Conclusions

Compared to the classical broadcasting systems, DAB by default provides almost deterministic QoS guarantees, by fully exploiting its design objectives and specifications. As far as other forms of digital audio broadcasting are concerned though (as the IP-based broadcasting ones), providing deterministic or even statistical QoS is not always achievable. By the use of an appropriate signal management system, like the one described in Section 2, a minimum level of QoS can be guaranteed.

Acknowledgments

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References

[1] R.K. Jurgen, “Broadcasting with digital audio”, *IEEE Spectrum*, vol. 33 (3), pp. 52-59, Mar. 1996.

[2] R. Rebhan, S. Olsson, B. Wergeland, P. Karlsson, and O. Franceschi, “Multimedia goes mobile in broadcast networks”, *IEEE Multimedia*, vol. 4 (2), pp. 14-22, 1997.

[3] W.Hoeg and T.Lauterbach, *Digital Audio Broadcasting: Principles and Applications*, Wiley 2001.

[4] M. Grube, P. Siepen, C. Mittendorf, M. Boltz, and M. Srinivasan, “Applications of MPEG-4: Digital Multimedia Broadcasting”, *IEEE Transactions on Consumer Electronics*, vol. 47 (3), pp. 474-484, Aug. 2001.

[5] C. Aurrecoechea, A.T. Campbell, and L. Hauw, "A Survey of QoS Architectures", *ACM/Springer Verlag Multimedia Systems Journal*, Special Issue on QoS Architecture, vol. 6 (3), pp. 138-151, May 1998.

[6] P. Karampiperis, N. Manouselis, A. Maras, and I.O. Vardiambasis, "Towards the design and implementation of a novel Digital Audio Broadcasting platform capable of analogue, digital and internet broadcasting of multiplexed multimedia signals”, *Proceedings of the International Symposium on 3rd Generation Infrastructure and Services (3GIS), Athens, Greece*, pp. 46-49, Jul. 2001.

[7] I.O. Vardiambasis, N. Manouselis, and P. Karampiperis, "Implementation of a novel Digital Audio Broadcasting (DAB) platform for multimedia signals”, *Conference Digest of the 2001 Asia-Pacific Radio Science Conference (AP-RASC’01), Tokyo, Japan*, p. 308, Aug. 2001.

[8] G. Lu, “Issues and technologies for supporting multimedia communications over the Internet”, *Elsevier Computer Communications*, vol. 23, iss. 14-15, pp. 1323-1335, 2000.