Personal Digital Audio Recording via DAB

Enhanced Radio as Interface

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Abstract

In this paper we present a survey above recent developments for improvement of Digital Radio receivers and a design of an Audible Content Manager based on Personal Audio Recording via DAB. The solution is based on a flexible framework (Java) which can establish fundamentals of a stand-alone or cooperative system in a convergent environment. This software based solution provides a basis for multiple configurations as well as an upgrade way for future applications.

Keywords

DAB, Digital Radio, Personalisation, EPG, XML, Java

INTRODUCTION

Traditional analog broadcast media like AM-FM-Radio and analog TV are meanwhile the last representatives of a media system which is not allowing to search or navigate through interesting content and does not enable to immediately store the items electronically. Now the current generation expects those behaviors from all media devices or they turn away from radio and TV. Future broadcast devices will provide solutions for an extensive multi-channel content access with on-demand facilities combined with huge storage capabilities also for portables.

In the last decade much effort has gone into the development of additional data services for Digital Radio. Based on PAD and NPAD numerous qualified services were established as we know them from similar WWW-applications (weather, traffic, news etc.). Now the Digital Audio Broadcasting is likely to turn from a classic audio receiver into a more sophisticated media platform with interactive, networked, enhanced interface, and on-demand qualities. Now data services in many cases should improve the usability of the receiver itself. Under the slogan ”digital information anytime, anywhere, anyway” is a lot of work in progress to establish synergy and harmony between digital broadcasting systems, the Internet and systems of the communication area. Significant indicator therefore is the increasing convergence of many standards on the one hand between radio and TV and on the other hand between organisations like ETSI, CCITT, ITU, ISO, W3C, and IETF.

The future radio consumption will be increasingly flexible and also independent from the schedule of the broadcast stations. More and more people will overcome the habits of a “rendezvous-listening”. It is to observe a clear trend to enjoy audio media more and more independent from temporal and geographical constraints (Figure 1).

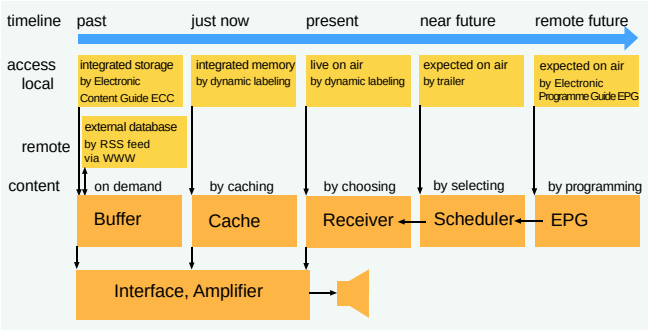

Figure 1. Time-dependent content access

In this paper we will discuss recent system developments of Digital Radio and propose properties of an Audible Content Manager based on a Personal Audio Recorder. The presented system consists among other things of an Electronic Programme Guide, an interest filter and a recommender of audio content.

TOWARDS A PERSONAL AUDIBLE CONTENT MANAGER

Multi-Channel and Multi-Standard Receiver

In the future the separation between Digital Radio (DAB/DRM) and TV (DVB/DMB) as well between live and stored programmes will disappear in a certain manner. Instead we will observe a limited variety of narrow- or broadband bearer systems with graduated capabilities and smooth transition. They are different in performance and will be general able to send audio and video content; they will present sound stand-alone and if desired or if applicable in combination with fixed or moving images. Hence, a DAB receiver is only one interface among many others for an Audible Content Manager.

Another trend is seen in the hybridisation with mobile phones (GSM and its successors as the 2.5G GPRS/EDGE and 3G UMTS) to gain access to the Internet and to individual on-demand media services. All the mentioned standards use COFDM in slightly modified manner and work in different frequency ranges. There are also numerous standards for the transmission of audio as MP2, MP3, AAC, and soon IP datacasting.

Diversity, additionally increases by the wireless access to the Internet, is the way to gain live or archived content in a geographical independent manner. Because radio

programmes are reachable over the Internet, it is possible to access them from anywhere. The most common way to gain internet radio was via streaming technology, nowadays the consumption of stored content by podcasting is an ever growing habit. That's why in the future ever more devices will be equiped with a wired (home) or wireless (automotives, portables) Internet access. Hence a new era of Babylonian confusions of methods, modes, and standards is raising.

Nowadays there is a real chance to apply the far sighted concept of Software Defined Radio SDR [1] for a wide range of different radio implementations in software which are evolving towards high levels of complexity. The main advantage of this approach is to offer cost-efficiently the ability to update software, customise new attributes or features and enable new versions of receivers. The need for multi-standard solutions to move multi-channel solutions into the practice is evident by the demand to consume media content on a broad range of platforms. First devices as multi-standard tuners are on the market [2][3]. Sometimes there is a confusion with the term smart or cognitive radio, but they will avoid transmission problems by switching to parallel frequencies. During the coming decade, cognitive radio applying adaptive software could be reconfigured on-the-fly as a universal communication device. They can change their communication functions to fulfill the demands of the user or the networks.

Time-independent Utilisation and Customised Personalisation

Another main trend of media consumption is the time-independent utilisation due to the increasing social mobility. Unlike to the utilisation patterns of the past now there are more options for media access. The time-related audio access may be expanded from:

- current "live" programme by labeled content,
- to the near future by labeled trailers,
- to the remote future by an Electronic Programme Guide
- backward to the perfect (last minutes) by caching and
- to the past by stored content in an archive via an Electronic Content Guide ECG or by WWW access via wireless or wired technology.

The caching or time shifted playout of audio let users pause, rewind and record live audio, mostly to a removable storage or to the internal memory currently for a maximum of 10 minutes. This principle is also named Rewind Radio or ReVu™ [4], the available storage time will increase certainly. Local storage is also a problem of information retrieval. The files generally have a label with station ID, date and time stamp, an additional description of the content is highly recommended. Therefore an Electronic Content Guide ECG is an inevitable condition, because the capacity of actual audioplayer encompasses. If the desired content is not in the local storage, it is possible to search the Internet for archived audio, especially by podcasting. This requires a wireless (mobile phone, WLAN) or wired Internet access. The idea of content referencing is to find an unique object in a location independent way. This is the same problem to locate an item in a distributed memory of a computer system.

For programmes in the near future (one ore two weeks extending in the future) an EPG enables users to browse programmes for events at a particular time, see a short description of each programme, and select them for scheduled listening or recording to the memory or removable storage. This principle allows in a sophisticated manner to find, choose, listen and record audio content even in handhelds as we know it from DVB-recorders. The first EPG for DAB were established in spring 2005 by the BBC, also Deutschlandradio has made a test for one week in September of the same year. This technique mostly bases on developments for Personal Video Recorders, but there is a separate standard for Digital Radio [5]. The function of an EPG depends on a mature concept of metadata description by XML. With such a information system it is possible to implement a completely automatic scanning system for desired content by a personal interest filter based on a profiler-recommender system. The personalisation of radio concerns content, presentation, and utilisation patterns. All these developments may change sustainable the way how people will listen radio [6].

The automatic content analysis by semantic methods will become more important for automatic storage. A first coars grain genre classification for the assignment of recorded audiofiles was implemented as a beginning of a hopeful advancement [4]. On the other side we also observe semantic and social music online recommendation services which allow to specify favourite characteristics. In this manner it is possible to offer similar audio content in the Internet [7][8]. Hence, all semiotic levels will be involved for content search and description, see Figure 2.

semiotic level	*traditional access*	*advanced access*	*method*
pragmatic	advice from acquaintances	recommender, profiler	adaptive sytem
semantic	mood-dependent selection	semantic analysis	pattern recognition
syntactic	printed programme, journal	dynamic label,EPG	parsing

Figure 2. Semiotic levels and content access

Multimodal Interface: Display and Speech

Further developments of modern radio reception concern interface solutions. For interaction with a display it must be found a compromise between convenience, size, and an affordable price. There is a broad variety of monochrome and colour 2x16 (or 2x20) character LCD text-only displays and full graphical display (128x64 pixels) or QVGA (320x240 pixels) and a fully functional graphical user interface. Another solution is an external device connected by infrared or bluetooth standard especially in cars. The connection of a keypad and a rotary encoder is often supported by the receiver module [9]. For home applications there are also boxes as PC-

controlled modules connected by USB [10][11][12]. But only a few are streaming audio via USB, some receivers use an optical digital output channel. Nowadays more and more devices are upgradable via USB port. A generic USB channel will be standardised soon for all DAB receivers [13].

Because a lot of information is simultaneously transmitted as text messages in a data service environment, it is obvious to apply text-to-speech and automatic speech recognition solutions for a communication by speech assistance, because displays are often not appropriate. The benefits of an automatic speech-conversation system have drivers, people who possess a receiver without a display or visual impaired persons. There will be car radio providing local hazard warnings in spoken form as well. Several solutions already exist for "audio-anytime" in car radios (TopNews). First interactive speech-enabled TV-EPGs and voice feedback radios which read out scrolling texts are developed [4][14][15][16].

Concept of an Audible Content Manager

The whole architecture of such a contemporary approach for an audio device consists of a poly-band tuner inclusively web-access, an audio manager for control of the input channels, the audio storage and the syntactic respectively semantic analyser in connection with a recommender-profiler. The interface will include text, graphics and speech components and a fast universal USB channel, see Figure 3.

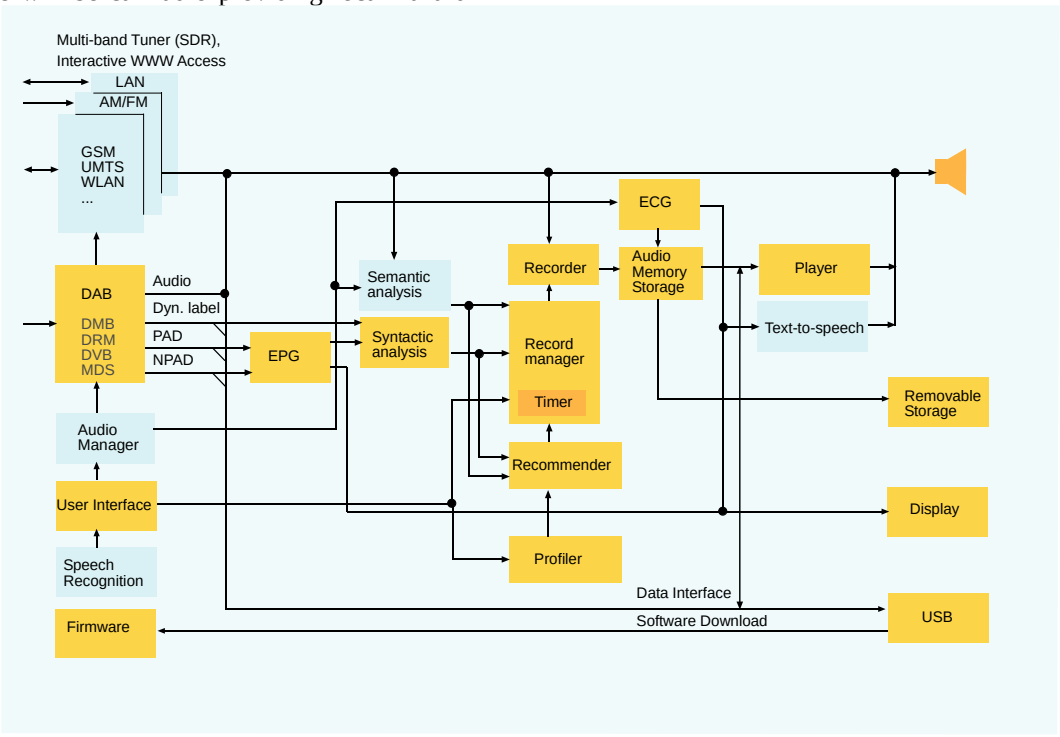

Figure 3. Audible content manager (dark: processed, light: work in progress)

DESIGN OF A PERSONAL AUDIO RECORDER

Aim of our work was to develop a software system, which is able to play back, record and display Audio and Data Services intelligently, which are sent via Digital Radio DAB. Useful additional transfered data is firstly the Dynamic Label, which presents current information to the running service, e.g. the current title of the programme, and secondly the EPG, which affords service information similar to well known, printed programme schedules. Because our main focus is the automatic and personalised recommendation and recording of programmes which are probably interesting for a user, we developed a system, which allocates all available information and adjusts its behavior correspondingly. It is distinguished between:

- general ensemble information,
- service-corresponding information
- user-specified interests,
- automatically achieved data, dependend on the user's behavior.

These information are the central elements in a DAB Personal Audio Recorder and Recommender.

For accessing digital audio services and its corresponding data, we use the Terratec DR Box 1 [11] which allows parallel access to all services of a chosen ensemble. So it is possible to analyse content of multiple Dynamic Labels or record several services simultaneously.

At first the accustomed functions of a Digital Radio must be included in a Personal Audio Recording System. These are:

- the selection of a service,
- a start and a stop button for manual records,
- the current time,
- a display panel showing the Dynamic Label.

For implementation we used the platform independent programming language Java and the IDE Eclipse. To handle the Electronic Programme Guide the Java Architecture for XML Binding JAXB was used. This technology allows to work with existing instances of

XML schema definitions, which are standardised for the EPG.

Software Design

A clear and well-planned design of a Personal Audio Recorder is required to ensure the permanent adaptation to the constant enhancements in the field of digital broadcasting. Thus we use a modular design with regard to a strict division between all functionalities, the available data and their visual representation and use the Model View Controller Pattern MVC. Figure 4 shows the essential components of our application.

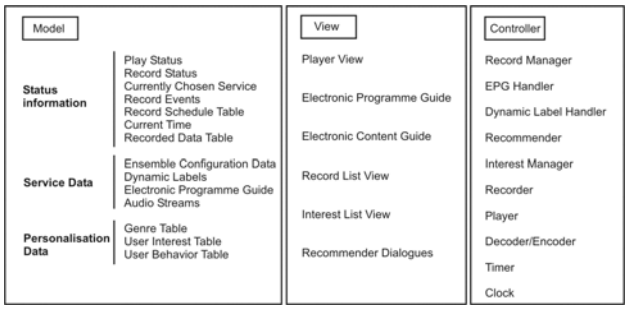

Figure 4. Software Components

All occuring data and information are represented by the model of the system. It is differed between status information, ensemble and service data and personalisation data. The view represents the user's sight on all data and functionalities. The easy and intuitive presentation is a big challenge, because all information should be available for the user, but must not overstrain him because of to high complexity.

Every access and modification of data occurs in a special controller. The several components are explained in the following sections. Thereby the functionalities are examined on the basis of the appearing model data.

Status Information

Status information describe the current state of our radio application. These is mainly the current chosen service, if one or more records are started and how many record events are written into the record schedule table. Furthermore a table exists, in which already recorded programmes containing relevant information are stored. This is first of all required to use the Electronic Content Guide ECG and comfortably browse all saved audio data.

Service Data

Service Data are all information of the ensemble configuration and its separate services. These are for example basic details on the location of the accessing data and the content and audio data itself. In the following the two basic service data, the Dynamic Label and the Electronic Programme Guide are explained more precisely.

Dynamic Label

The Dynamic Label offers current textual information about the running programme and can be shown during the playback of a service. It consists of maximal 128 characters and ideally describes the title of the current programme (or the current track) and perhaps the current date. So the Dynamic Label is an interesting approach to detect user interests. So far the assembly of the content of the Dynamic Label is left to the stations. For better usage a standardised description syntax would be desirable, for example for the 128 characters:

```
<Title of Programme> <Title of Track>
<Additional Information> <Duration>
<TVAnytime Codes>
<Number of belonging DLs>
```

An classification of the current programme is achieved by a field containing one or more TVAnytime codes. Because it is possible to sent two or more Dynamic Labels in series to achieve 256 or more characters, the last field defines the number of Dynamic Labels belonging together.

The indication of the beginning and the duration of separate programmes and tracks is a considerable problem in a Personal Audio Recording System. With synchronous transmission of the Dynamic Label and the audio stream, that means delays less than a second, it can be used next to the EPG to identify start times and the duration of particular programmes or tracks to allow accurate recordings.

Until now the Dynamic Label mostly arrives with an unpredictable delay of 5 to 15 seconds. Methods to record interesting contents precicely are discussed. For example it is possible to buffer incoming audio data to extract interesting content afterwards.

Electronic Programme Guide EPG

The EPG offers all service- and programme information to plan records. These are the title and genre of a programme, a description as well as the start time and the duration of a programme. The standardised EPG [5], delivered in XML language format, is sent via DAB as PAD from a single station or considerably improved for the whole ensemble by NPAD.

An important function of the visual representation of the EPG is the possibility to select single programmes and flag them for recording. So the complicated specification of start- and stop times is not applicable. The user handles separate programmes as objects or events.

Personalisation of Data

To personalise radio play back and recordings based on user interests, several data are required. Besides manually user-specified data a lot data is gathered from automatic analytical methods. These data are processed in a so-called recommender, which decides on the further proceeding.

Interest Management

The Personal Audio Recorder offers the user to configure her/his interests manually. Thereby one can choose genres and favourite topics from a default set or define own keywords.

Syntactic and Semantic Analysis

The information provided by the EPG and the Dynamic Label are analysed for their content. Thus defined keywords and favourite genres are detected and the system can recommend accordant running programmes or automatically mark them for recording. With text retrieval algorithms all textual fields like the title or the description of a programme as well as the whole Dynamic Label are searched. If many descriptive information is broadcasted, its easier and much more precisely to decide, if the content appears interesting.

User's Behavior

Beside the information broadcasted by radio stations, the behavior of the user is analysed to improve the personalisation and automation of recommendings and records and to satisfy the user's needs. Important aspects are:

- temporal listening habits,
- areal listening habits,
- favourite services / artists / genres / topics.

If the Personal Audio Recorder is used over a long period, the system adjusts itself to the user's interests.

Recommender

All mentioned information are gathered in a Recommender. If a programme is classified as interesting, following reactions can occur:

- automatic record or scheduling of a record,
- automatic tuning to another service,
- Pop-up Window with a recommendation.

To decide properly, the Recommender must also know all status information. For example the user is currently listening to an interesting programme, she/he should not be disturbed by a recommendation. In this case an alternative action is the automatic record of the programme and the later note in an Electronic Content Guide ECG.

Further Components

Record Manager

The Record Manager is a system which schedules and controls all records. Because records can be manually or automatically set from different functions, they are called Record Events, which contain all required information to handle them without any conflicts. Thereby all Record Events are stored in a so-called Record Schedule Table, where all entries are stored according to date. Several timer processes of the Record Manager start and stop these Record Events by running a recorder and will be deleted, if they are worked up.

Recorder

All Record Events contain information like the location of the audio stream or the title of the programme. Record Events are sent from the Record Manager to a Recorder, which records the incoming MP2-Stream and converts it to an adequate file format. Of course many recorders can work parallel and record different programmes. The only limitation is that it is only possible for services in the same ensemble.

Player

Besides the regular play back of the incoming audio stream the recommender can automatically tune the player to an interesting service. Furthermore the player has the functionality to play back already recorded data.

Electronic Content Guide

The Electronic Content Guide ECG is a similar term compared to the Electronic Programme Guide which contains future programmes. The ECG in contrast describes the local storage of archived data with all relevant information. Search- and filter functions allow to handle the fast growing amount of sound data. In combination with the Recommender the stored items can be used to automatically generate whole programmes.

IMPLEMENTATION OF AN EPG AND INTEREST FILTER

Introduction

The EPG is a data service used to provide temporal and descriptive programme information as well as detailed information about the contents of broadcasted media. Compared to printed programme schedules an EPG offers many more possibilities:

- covering more content,
- immediate reaction to modifications,
- adaptable visualisation according to the capabilities of the device,
- multimodal presentation (visual, audible...),
- linking to corresponding information,
- explicit referencing of content by a unique identifier.

The DAB EPG Standard

The WorldDAB Forum has developed a specification to provide EPG information as XML files [5][17]. We have implemented an EPG for DAB based on this specification and used it as a fundamental part for the Personal Audio Recording System. So far (07/2006) there is no German DAB provider broadcasting EPG data so we had to create our own files for testing the system.
We used version 1.3.1 of the specification, published in February 2006. XML schema files for DAB EPG in Version 1.1.1 and 1.2.1 are available at the WorldDAB website [18]. Unfortunately there are no schema files for version 1.3.1, so we took them directly from the ETSI document.
The standard provides two information classes: service and programme information. Service information contains details about ensembles and services, e.g. ensemble- /service-identifier, label, description, frequency and bitrate. A programme is a piece of content. Figure 5 schematically shows information provided by a programme instance. Note, that elements with dashed borders are not mandatory.

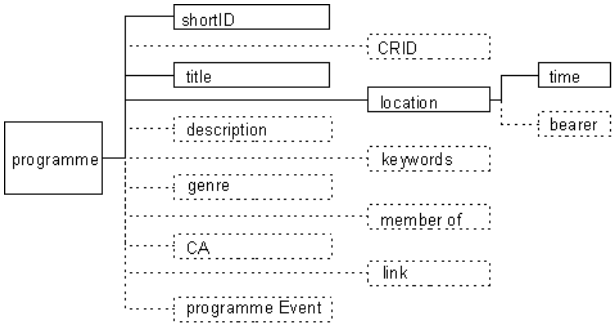

Figure 5. Content of EPG Programme Element

Programmes can be assembled to create a schedule. According to the aim of our work we created some XML instances containing schedules, respectively for one day and one service.

Content Classification

Several genres may be assigned to a programme. The declaration of a genre is based on the TV-Anytime specification ([19] Annex A). A programme may be classified according to several aspects ("Classification Schemes"). The TV-Anytime standard uses an URN containing the Classification Scheme, the version (year) and a number code indicating a value e.g.:

`urn:tva:metadata:cs:ContentCS:2005:3.1.1.1`
indicates "Daily News"

`urn:tva:metadata:cs:FormatCS:2005:2.1.4`
indicates "Documentary"

`urn:tva:metadata:cs:IntentionCS:2005:1.2.3`
indicates "Infotainment"

The first example shows classification by content, the second by format and the last by intention. Other supported classification schemes are: OriginationCS, IntendedAudienceCS, ContentAlertCS, MediaTypeCS, AtmosphereCS ([5] 5.2.6).

This classification provides an approach for interest based filtering of content, as used in our system.

Content Referencing/CRID

A programme may have an identifier, allowing time- and space-independent references to this piece of content. This identifier is a CRID (Content Reference Identifier). CRID was developed by the TV-Anytime Forum used as worldwide, unambigous identifier for media content [20][21]. An CRID consists of an authority and a data part: "`crid://<authority>/<data>`".

Annotations to the Standard

As shown in Figure 5 most of the information in a programme is optional. Only the following elements are required:

- identifier (shortCRID),
- name,
- start time,
- duration.

All other data are not mandatory. This poses some problems to discuss before implementing the system. First of all, an interest filter does not simply work without content classification. A possible solution is to analyse title and description of the programme using information retrieval methods. Secondly, the CRID as unambigous identifier is not required, just a version called "shortCRID". ShortCRID is an integer value between 0 and 16777215. It is unique only in terms of a service and a period of half a year. To identify a programme we used a combination of shortCRID and service identifier.

A special problem is that a programme may not be unambigously assigned to a service. There are several possibilities for assignment, but they are not required. Firstly the declaration of the containing service is not mandatory in the programme and in the schedule. Secondly, if the EPG data is sent via PAD, the assignment is possible but it also makes sense to sent all EPG data for an ensemble via NPAD. Finally the DAB EPG standard provides a filename convention containing the service identifier. However, the convention only describes how to name one file per service per day and the standard allows to insert information for several services into one file.

As a solution we developed the following proposals and adhered to them in creating the test files:

- containing service must be declared in the schedule element,
- programmes must not appear outside a schedule,
- one file per service per day, following the filename conventions,
- every programme has one or more assigned classifications,
- usage of a sequential shortCRID number starting at 0

Implementation

We used the JAXB-compiler (xjc) to generate Java-classes from the XML schemas given in the standard document. The module "EPG Handler" reads the available schedule files and creates a "Programme Element" object for every programme found. A Programme Element contains the following data:

```
XMLElement (representation)
shortCRID (integer)
crid (string)
serviceId (string)
title (string)
start time (GregorianCalendar)
duration (Duration)
short description (string)
description (string)
classification (list of strings)
```

If there is no information given for one of the data fields, the field remains empty (null).

All created Programme Elements are stored in a list. The approach to map the programme data to an user defined object was chosen to get more efficient access to the data.

EPG Viewer

The EPG Handler provides methods to get the Programme Elements for a specific date and service. Using these methods the EPG Viewer creates a programme table for a whole day that shows each service in a separate column. Each entry may be flagged by the

user for recording. If the user chooses a programme to record, a Record Event will be created and sent to the Record Manager.

Interest Filter

The interest filter accesses the interest table containing user-defined interest data and searches the genre information from the Programme Elements. If it finds matching classifications a record event from the containing Programme Element will be created automatically and the entry will be marked in the EPG view. Some more sophisticated approaches to interest filtering will be discussed in the next paragraph.

Further approaches to interest filtering

Programme Groups

The DAB EPG standard allows to assign programmes to a Programme Group. Programme Groups are used to combine programmes, e.g. programmes with similar themes or serials. A Programme Group may be member of another Programme Group so one may create a hierarchical system of Programme Groups. If a user is interested in one programme she/he may be interested in other programmes of the same group too.

Learning system

A learning system analyses all information e.g. what the user is hearing, recording and what she/he is interested in. It generates a user profile and uses this as base for recommendations and automatic recordings.

Interest Filtering without Classification

If the EPG data does not contain any classification information an interest filter may use title, description or keywords to find interesting programmes. Assuming a return channel, links to related information or the content reference idea may be used to get more information about the programme.

EPG Data Volume

The test files created by using programme information of a popular broadcast service are about 30 KByte per service per day. The service provides programmes of about 15 to 60 minutes duration and hourly news. Assuming EPG data for 30 different services and 14 days there will be an amount of 12 MB to store locally at the device. By using the binary format described in [22] we were able to reduce file size to approximately a third. Because the binary format encodes only the XML tags it is evident that there is much overhead in the XML data, proportionally reducable by adding more content to the files.

GRAPHICAL USER INTERFACE

An exemplary implementation of a GUI is shown in this section. It depicts the most important components and the user interaction. Thereby the controls and views are separated in several windows components to easily adapt the system on portable, graphical devices, e.g. PDAs.

The player window provides basic functionalities to choose a service and to start a record, see Figure 6. It shows the current service and the Dynamic Label and contains buttons to access all other components.

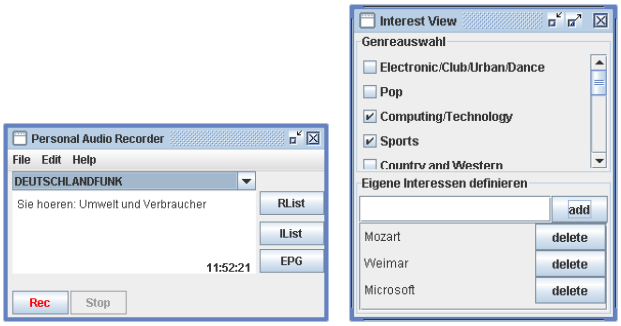

Figure 6. Player and Interest Manager View

The Interest Viewer allows the user to set interests on a list or delete them. Furthermore one can define own interests and keywords. The Dynamic Label is continuously analysed for defined interests, so automatic records can occur instantly.

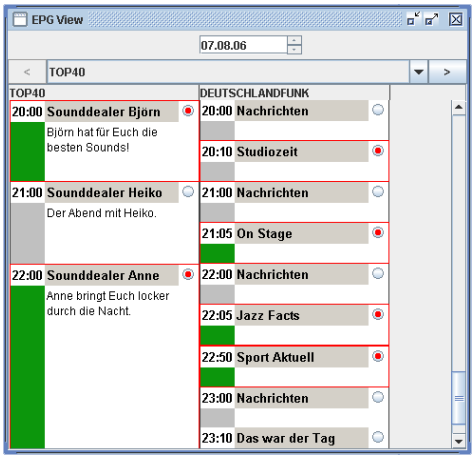

Figure 7. EPG View

Each programme is shown as a table entry with title, start time and description, see Figure 7. It can be flagged for recording by using the radio button top right. The dark green bar at the bottom left indicates a recommended event which is automatically set for recording if the user specified it. The marked radio button indicates a programme which is flagged for recording. If services are in the same ensemble, concurrent records can occur.

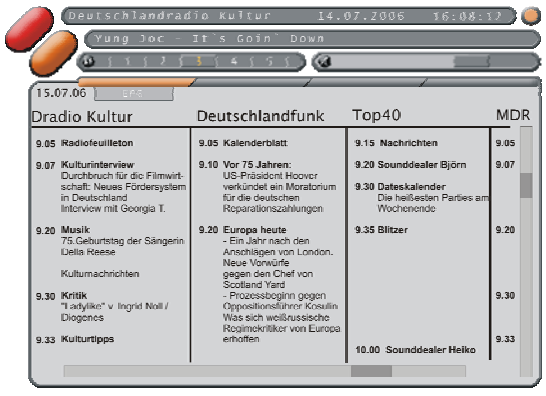

Figure 8. Player Design

Another example for an advanced design is shown in Figure 8. The player/recorder thereby integrates the EPG view.

User Experiences

The current state of our work did not allow a comprehensive evaluation of the system, however some people tested the hole system. The purpose was to identify weaknesses and to offer suggestions for improving the system. The appliance of the Personal Audio Recorder attracted interest and is generally considered as easy and convenient. Most people show interest in a solution providing audio- and metadata simultaneously and believe that the system is encouraging to listen more attentiv, for longer and at different times.

Usability Problems

A specific problem is the granularity and depth of provided classifications to choose in the Interest Manager. Intentional our system provides only a small choice of content classification. The TV-Anytime standard [19] allows more than 1000 different classification statements in several categories, what is difficult to provide without overstraining the user. On the other side the offered descriptors are often not suitable enough for a sophisticated audio classification.

The number of interaction dialogues must be adapted well considered. A strict balance between disturbing the user and a pleasant personalisation of the system must be found. Another challenge is the adaptation to portable devices. Therefore the design of appropriate interfaces and principles of user interaction is required.

CONCLUSIONS AND FUTURE CHALLENGES

In this paper we reviewed novel developments for improvement of Digital Radio receivers and discussed an Audible Content Manager based on DAB. We designed a customisable radio system by combining existing technologies and offer an approach for user-friendly, trend-setting radio consumption. Thereby it was our aim to include all available information like the Dynamic Label, the EPG or all user data to personalise the system. A prototype of a Graphical User Interface clarifies the functionalities. Several useful extensions for the future work are:

- voice control and synthetic voice,
- comprehension of more variables to detect user interests,
- connections to sound data bases,
- remote control of the Personal Audio Recorder,
- export functions to mobile applications,
- feedback channel,
- comprehension of Digital Media Broadcasting DMB.

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