

IP based enhanced Data Casting Services over Radio Broadcast Networks

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Abstract : Emerging technologies like ATM, WDM or xDSL enable broadband communication over wireline networks. In future every user could be equipped with a broadband access point to multimedia information and communication data services. Mobile data systems like GSM or even UMTS are lacking in bandwidth for broadband multimedia. Furthermore the raise of the internet information systems like the WWW increases the desire for broadband multimedia information and communication services also for wireless i.e. mobile users.

The system architecture, which is described in this paper, enables the realization of broadband multimedia information services for mobile users. The basic idea for the wireless provision of multimedia services to the users is the usage of digital radio and television broadcast networks like DVB-T (Digital Video Broadcast - Terrestrial) or DAB (Digital Audio Broadcast). Though these networks only support unidirectional data casting, they provide sufficient bandwidth for multimedia information services with a large number of users. An interaction channel for upstream communication to request information is integrated in the system using different approaches with GSM data services. The system architecture is structured in components with standardized interfaces to be flexible in regard of the realization of a specific service. The internet protocol IP is the basic means of interconnection for our system to form a flexible multiservice network. The system architecture has already been implemented in a prototype information service system, which enables WWW access over DVB-T and is on its way to become a product.

Keywords : multiservice broadcast networks, mobile internet access, broadband mobile networks, multimedia information services

1 Introduction

The ongoing technical progress of communication networks forms the basis for new communication and information services. Broadband communication networks based on ATM, WDM for wide area networks, xDSL for access networks or even high speed internet enable multimedia communication for a large number of users over wireline networks. In addition, new services are not only supported by the technological advancement but also emerge of the interconnection and the interworking of different networks and services. In this way traditionally separated networks are able to provide services for which they were originally not designed. Examples are telephony over internet or video-on-demand, which combines distribution networks like cable TV and telephone networks, or the use of digital radio broadcast networks for IP based information systems combined with GSM to realize interactivity. The latter will be the focus of this paper. This convergence of networks helps to overcome restrictions in networks which hindered multimedia communication before.

Especially for mobile users the available communication bandwidth is still too small to provide reliable multimedia data services. But the enormous growth of interest in the internet and its multimedia data services like WWW leads to a rising demand for mobile access. Imagine driving in a car through the country and being able to access multimedia tourist information on your way, wherever you are. In addition to that you may be able to have the latest traffic reports

displayed on your mobile terminal and request a specific route plan that guides you to your next destination according to actual traffic conditions. Current mobile networks like GSM [1] are not suitable to support this scenario. Even UMTS (up to 384 kbit/s for mobile terminals in city micro cells), the future mobile communication system succeeding GSM, will not suffice in order to provide broadband data services to a mass of mobile users.

Generally speaking the requirements for wireless multimedia data services according to the sketched scenario are:

- The wireless transmission has to be transparent for the applications.
- Multimedia information systems require asymmetric non-real-time communication channels with flexible bit rates.
- Bandwidth is to be shared among users to be able to assign it dynamically where it is needed (e.g. on demand).
- Beneath point-to-point addressing, data multicast as well as broadcast should be possible.

Based on the considerations stated above a system concept was developed and implemented at the Institute of Communication Networks of the Munich University of Technology (TUM) together with partners from industry. Our approach realizes a flexible system for the provision of broadband multimedia information services for mobile users. To proof the feasibility of our approach the system architecture has been implemented in an information service, which enables access to the WWW over DVB-T with common Web browsers on the mobile client side [2,3].

The paper is structured as follows. First we give an overview of the system concept and describe the system architecture. Section 3 elaborates on the broadcast unidirectional services network and describes the downstream communication path. Interactive services are provided with the use of a return channel, which is described in Section 4. In Section 5 we show some example application scenarios for our system and discuss traffic and bandwidth design parameters. An outlook on a prototype realization and a conclusion summarize the results.

2 Concept and system architecture

Our goal was to provide mobile users with a flexible broadband wireless multiservice network in order to give them the possibility to use multimedia information and communication services. With GSM already

providing good real-time person-to-person communication services, and having the growing interest in internet-like information services in mind, we focused on non-real-time services. Some example services that we consider are:

- static WWW like information services, e. g. city information;
- dynamic information services, e. g. electronic newspapers, traffic reports, stock quotes;
- individual communication and information services, e.g. email, fax;
- interactive communication and information services, e.g. WWW browsing, chat.

Our vision was to integrate different wireless communication infrastructures into one flexible and generic system architecture in order to provide the user with a suitable and easy-to-use access to the mentioned multimedia information and communication services, as illustrated in Figure 1.

In this architecture, two interfaces shield the service control and the mobile user from the underlying networks. To be transparent for a wide area of applications the interfaces are based on the most commonly used protocols, the TCP/IP protocol stack. Dependent on the desired service and its requirements, the appropriate networks are chosen without the need of any explicit interaction by the user.

In addition to the independence from the underlying network infrastructure, the whole system architecture reflects our approach of modular decomposition in order to allow a wide area of applications. All system components, which are described in the following sections, are designed to be independent modules with common interfaces based on the TCP/IP protocols. The layered system modules can be used separately or in other combinations for any service realization.

3 Information casting

On the first view individual interactivity seems to be the dominating characteristic of internet services. But considering services like information or software download and data push, you will see that quite a huge part of the internet services are usually one way. These information or download services are accessed mostly by a large number of users simultaneously without any individual preferences. So broadcast would be more adapted to these services than setting up connections for each user separately. Especially for mobile users having only low bandwidth, broadband broadcast networks according to our concept will provide great value [3].

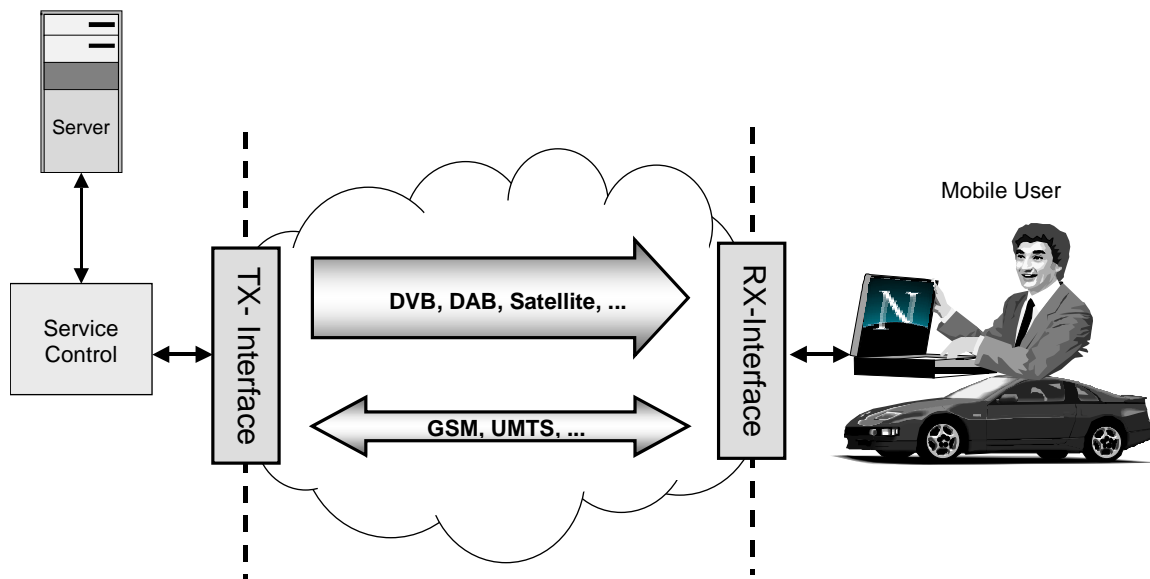


Fig. 1: Generic, flexible system architecture for mobile multimedia services

According to the general system architecture described above we will now explain some details of the components that form the downstream direction for data casting to the mobile end user.

3.1 Digital wireless broadcast networks

Digital Video Broadcast DVB and Digital Audio Broadcast DAB both represent the successors of the analog TV and radio broadcast networks. They are based on the MPEG transport stream for the coding and transmission of video and audio. Whereas DVB-T (DVB for terrestrial broadcast) provides more bandwidth per channel than DAB (8 MHz and 1.5 MHz, respectively), the latter is better adapted to mobile reception. However, both system standards already provide mechanisms for data casting within the MPEG-2 Transport Stream (MPEG-TS). For our prototype system, we concentrate on the DVB-T [4,5], as it offers a larger bandwidth (up to 38 Mbit/s). Other projects focus on DAB for the downlink channel [6].

DVB-T as well as the two other DVB main standards (DVB-C for CATV broadcast and DVB-S for satellite) uses the MPEG transport stream for a reliable transmission of synchronized audio, video and data. The information is transported in packets of 188 Bytes length. One transport stream can contain many different TV or audio programs or special data streams. Different programs are distinguished by Packet Identifiers (PID). Program Map Tables (PMT) and Program Specific Information Tables (PSI), which are identified by reserved PIDs, show the mapping of programs to PIDs.

For the transmission of additional data there are two alternatives. Either a special data stream with fixed

bandwidth is reserved and allocated by a PID in the MPEG transport stream. This provides a guaranteed data rate for a specific information service. But whereas most information services have no strict real-time constraints this reservation effort does not reflect the business case.

The second alternative is to use the spare bandwidth of the transport stream that is not needed for the audio and video information of the program mix. On the one hand the programs (approx. 5 Mbit/s for TV and 1 Mbit/s for audio) could never fill exactly the 38 Mbit/s TS. And on the other hand the data rate of the MPEG video coding depends on the video content. Scenes with high motion e.g. sports require more bandwidth than low motion scenes e.g. news reports. Empty stuffing packets are added to the information stream to fill up the bandwidth of the channel. We have concentrated on this second alternative to transmit data packets in the spare bandwidth of the TS.

The DVB specifications already provide mechanisms for data casting [4]. Of the four existing proposed standards we have selected the Multiprotocol Encapsulation. This standard defines the transmission of various communication protocols and especially of the Internet Protocol (IP). DVB adopts the DSMCC standard and provides datagram_sections as data frames of 4098 Bytes length for the data transmission. These frames are mapped into the 188 Byte MPEG TS packets in the IP-packet inserter that has been implemented in our project. Figure 2 illustrates the insertion of IP payload in the empty stuffing packets of the MPEG Transport Stream.

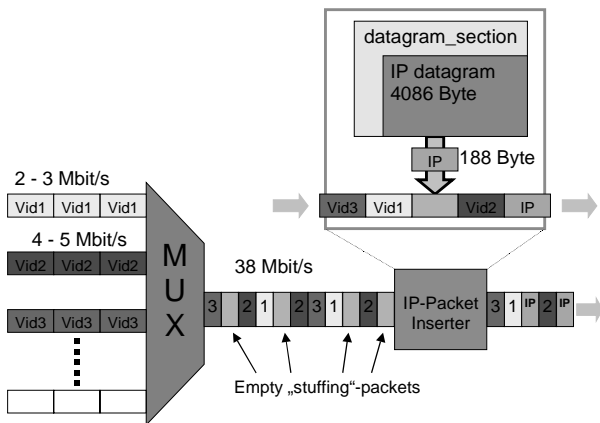


Fig. 2: IP-Packet Inserter for DVB-T

Figure 3 shows the complete downstream transmission part of our system architecture consisting of an IP-packet inserter at the transmitter side and an IP-packet reader at the receiver side. These modules provide a simple interface based on the IP protocol for the transmission of data within the DVB broadcast system.

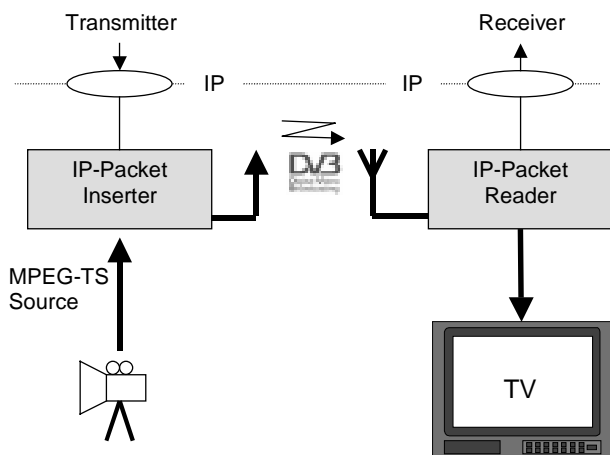


Fig. 3: Downstream channel over DVB-T

For the prototype system we have implemented a packet inserter and a packet reader using FPGAs programmed with VHDL [2]. MPEG-TS null packets, which exist in every transport stream to stuff up the MPEG stream to 38 Mbit/s, are used for the transmission of the IP packets. Transmission rates of more than 5 Mbit/s have been realized and tested in field trials.

3.2 TCP/IP tunneling for unidirectional connections

As mentioned in Section 2, the DVB transmission system will be connected on transmitter and receiver side to two interfaces. The task of these two interfaces

is to shield the service control and the user from the network dependent restrictions, particularly from the unidirectional IP-based connection.

As most services in the internet rely on TCP/IP connections, it seems to be logical to use this connection type on the service control and on the user side of the two interfaces. As TCP is a bi-directional protocol, the mentioned DVB transmission system can not be used directly for TCP connections.

Compared to Figure 1, one way to solve this problem would be to use a bi-directional network, i.e. GSM or UMTS, as return channel for the TCP connection. Even if this might be a feasible way for interactive and user individual services, it is not in case of unidirectional, especially multicast or broadcast services. High costs for the provisioning of the return channel prevent from using additional systems only for acknowledgements. In addition the MPEG TS provides a very reliable media for data packet transmission.

For these kind of services where a return channel would not make sense, we invented a more efficient and better adapted solution, called TCP-tunnel, shown in Figure 4.

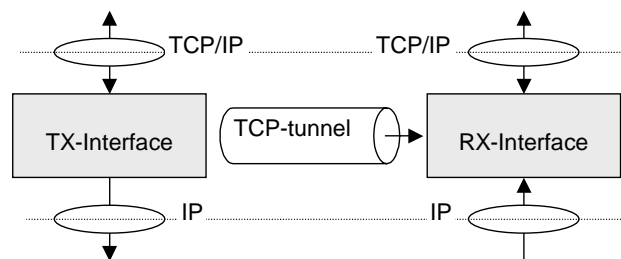


Fig. 4: The TCP-tunnel

The TCP-tunnel layer supports the use of the TCP protocol on unidirectional transmission channels. The system consists of two routers, residing at the beginning and at the end of the unidirectional channel. The router at the transmitter side provides the missing TCP functionality by generating the appropriate acknowledge messages for every incoming TCP protocol message. The router at the end of the unidirectional channel is analogous the sink for acknowledge messages originating from the final receiver of the TCP connection. In this way neither the sender nor the receiver have to deal with the unidirectional channel. Both have the impression of being connected to each other via a non-interrupted TCP connection. On this solution a patent is presently pending [7].

With this feature, the TX-Interface can choose freely which network to use without any impact on the service control or the user equipment.

3.3 Pushing HTML Pages

In this section, we want to show a sample service that can benefit from the mentioned network independence. This sample picks up the initial scenario and shows a HTML based information service. To benefit from the broadcast possibility, we describe a service where WWW pages are distributed to a large group of users. These pages could be tourist information, traffic reports or stock quotes for example.

Figure 5 shows the HTML push service. The broadcasted Web pages are stored in a proxy cache at the receiver side to allow the user to browse in the buffered pages with any conventional browser. A similar approach is shown in [8] but for Satellite Systems.

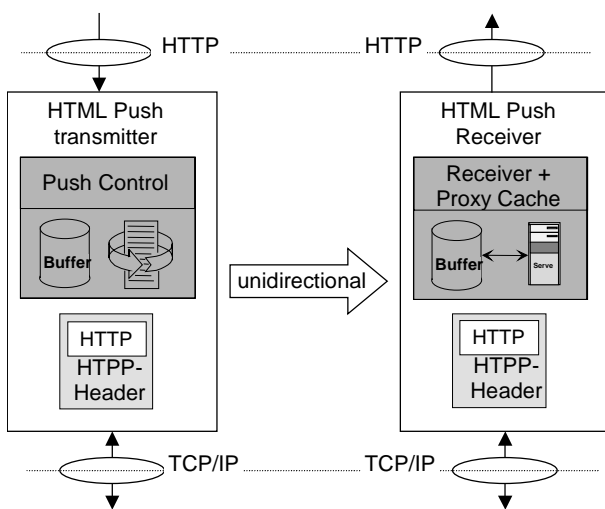


Fig. 5: The HTML push service

We have implemented a HTML push transmitter and a HTML push receiver for our prototype. A service control selects a number of desired HTML pages. These pages, usually downloaded over the public internet, are stored inside the Push transmitter in a buffer. On request of the service control, the stored pages are consecutively transmitted to the receiver using the interface to the TCP tunnel.

To make sure every receiver system could get the complete information the transmission process is repeated cyclical. This especially helps mobile systems with varying quality of the radio channel and systems that are not permanently turned on to not miss important information.

On the receiver side the files are stored and made available to the user by means of a proxy cache. In contrast to existing video-text services like the German one the user can browse through the locally buffered pages and has not to wait until the actual transmission

of a certain page in the transmission cycle. Any conventional Web browser could be connected to the proxy cache.

All HTML pages are transmitted as HTTP responses to be compatible to existing standards. But as the receiver does not send a HTTP request for the pages that are transmitted, additional information has to be added to the HTTP responses before broadcasting. To maintain the proxy cache, the receiver needs additional information like the source URL of the transmitted page and a time stamp to be able to clean up the proxy cache and delete non up to date information. For this additional information we have developed a Hyper Text Push Protocol (HTPP) that adds a special header to the standard HTTP files.

4 Interactive Services

Even if the described architecture serves well as a system architecture without a backward channel, for enhanced data casting the mobile user should also be able to select information, request special information pages or even have interactive access to user individual information.

4.1 Local Interaction

The system shown in section 3.3, where we described an enhanced data casting service, includes already a simple but effective way of interaction. The content pushed to the users' terminals is not immediately displayed but stored locally in a buffer. This allows the user to interact with his local system to select the interesting information he wants, within the broadcast information. This concept based on the principles of proxy caching could be used not only for HTML pages but for any kind of content, e.g. mp3 audio files or electronic newspapers.

4.2 Personal Interaction

The service system described before provides interaction only within a limited set of information, which was received by all broadcast receivers. Personal information requests could not be fulfilled. Therefore, an interaction channel is required. Digital radio broadcast networks provide sufficient bandwidth for enhanced data casting service scenarios but lack of an interaction channel. The combination of these broadcast networks with other mobile communication networks would help to solve this problem.

Different interaction channel concepts are possible, according to user requirements and service business cases. The general module required to complete our system architecture with an interaction channel is shown in Figure 6. On the service provider side, a

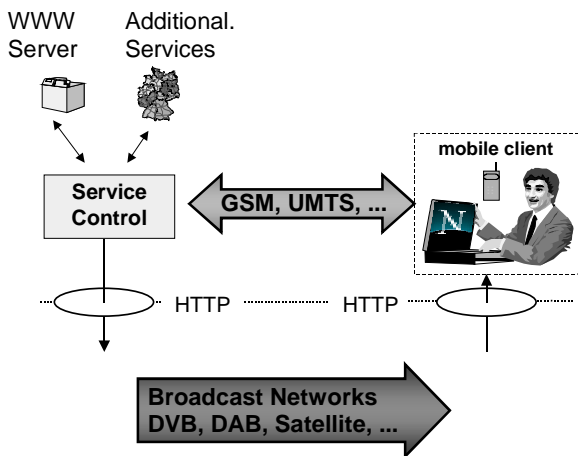


Fig. 6: Interaction Channel

server is required to respond to the requests, provide the information and to select the downstream channel to transmit the information to the user. The user terminal has to be equipped with the appropriate modules respectively to send on the upstream channel.

Depending on the degree of interactivity we distinguish two scenarios that could be realized with different system components. Lightweight interactivity requires a less complex and less elaborated interaction channel than full interactivity.

4.3 Lightweight Personal Interaction

Services with low interactivity, i. e. services that have only few user requests, will do with a very cheap and easy to implement solution. The GSM short message service is an effective means for the transportation of user requests. Since SMS is ASCII format the request can automatically be processed by the service control. We suggest this interaction channel for services that require short, one time requests with a broadband answer like route planning, mp3 audio files for the car radio or download of multimedia presentations for business preparation.

A SMS return channel has been added to our prototype information system, using a SMS to Email gateway provided by the GSM service provider. The Email server starts a service processing script on the recipient of an Email with a defined subject and extracts service information from the message body (see Figure 7).

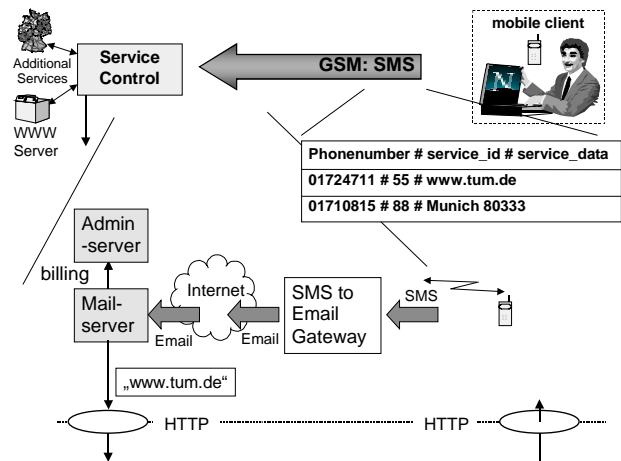


Fig. 7: SMS Interaction Channel

4.4 Full Interactivity: Intelligent Routing

More interactive services like full WWW access require an always-on interaction channel. Since most internet sessions are asymmetric concerning the bandwidth requirements for downstream and upstream direction, mobile communication systems like GSM or GPRS can be used as interaction channel [9]. This system concept is not only recommended by and defined in the standardization of the digital broadcast networks (e.g. for DVB in [9]) but also recommended by the mobile communications community [12].

Figure 8, which is taken from the DVB standards, shows the principle system structure for complementing an unidirectional DVB-T broadcast channel with an interaction channel.

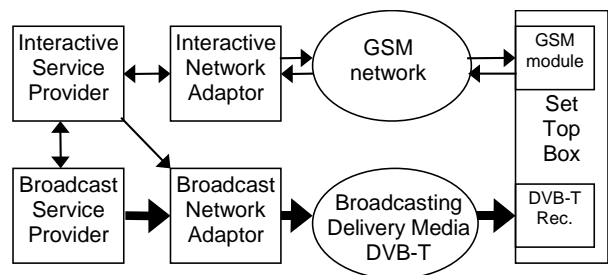


Fig. 8: ETSI Model for the interaction channel

To make the combination of networks again transparent to the user, an intelligent router has to be introduced on the service control side of the system. This router splits the TCP/IP connections and uses the broadband broadcast downlink whenever the GSM/GPRS connection is too slow. With this routing concept the TCP tunneling mechanism is no longer needed.

Figure 9 shows a scenario using an intelligent router to split a TCP connection between DVB-T and GSM.

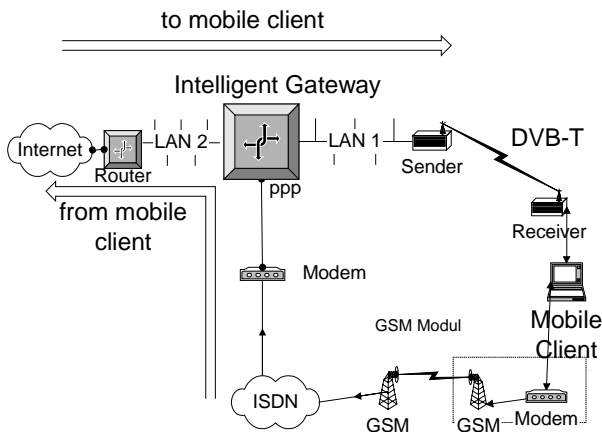


Fig. 9: Intelligent Gateway scenario

Beneath our concept other approaches exist, e.g. [10] describes a system architecture with the combination of mobile wireless systems and satellite broadcast systems for interactive communication to automobiles. In contrast to our multiservice system this approach, like others, only realizes a split connection integrating a broadcast media but does not use the broadcast service components for simple or advanced data casting or lightweight interaction scenarios.

5 System application scenarios and traffic estimations

The system that is described above serves as a platform for the realization of enhanced data casting services based on the TCP/IP protocol. To show the flexibility of the system we outline several application scenarios with traffic estimations in the following. Every DVB-T transmission channel has 8 MHz HF bandwidth. Depending on channel coding up to 38 Mbit/s for data are possible over one channel.

The application scenarios emphasize on the value of the described system for mobile users. Therefore the examples are taken from the automobile sector. Other application fields are also imaginable.

The cyclic broadcast of information pages (WWW pages) is considered to be the basic service application of the system. The pages are preselected by the service provider according to the service profile, e.g. traffic information or tourist information. A cyclic transmission as proposed in section 3.3 supports not only the complete reception of a certain information package but also allows to put emphasis on time sensitive pages. Pages containing timely material like

traffic jam reports could be inserted more frequently within the traveling information of the cycle.

Assuming an average HTML page including pictures having 30 kByte [11] 24 HTML pages per second could be transmitted within the bandwidth of one TV program (6 Mbit/s). This increases up to 122 pages per second if one DVB-T channel is used in total for this information service. In this way more than 7500 pages can be broadcasted to the users within a 5 minute transmission cycle. The use of a cell structure in the DVB-T network would enable adaptation of the transmitted content to regional information claims (e.g. local events). The MEMO project [6] proposes a solution of a DAB cell structure for data services. Not only regional requirements could be addressed in this way. Also the bandwidth of one DVB-T channel has to serve a less number of users. For user individual services, more bandwidth can be provided per user then. Of course such a cell structure imposes a great complexity on the system since e.g. handover strategies have to be implemented.

Whereas the information of the broadcast services described above is accessible via any DVB-T receiver for all customers, a specialized service would be the multicast of selected information. The customers could be charged for these services. Coding mechanisms in combination with multicast addresses and decryption keys will realize the multicast groups. Registering for these services would take place off-line. But also an on-line registration is imaginable e.g. via automatic call centers that enable the information access for a certain period of time starting immediately after the call. Nevertheless these closed user group services differ in the number of receivers and in charging principles but they do not differ from the conventional broadcast scenarios in bandwidth consumption.

More enhanced data casting services require an on-line interaction channel for the exchange of data with the service control. An in-car application might be the request of personal route maps. The route map is processed on request of the customer and sent in singlecast mode. In reality the personal route map is as well broadcasted to all DVB-T receivers but only the station of the requesting customer is able to decode it. Depending on the granularity of information needed for the processing of the service an SMS based solution as well as a solution based on a GSM data connection is possible.

If we assume that route maps and concerning information contains approx. 1 Mbyte of data, then the DVB-T system is able to serve one user request per second using the bandwidth of one TV program for data transmission. Data rates could be shared flexibly between TV broadcast and data casting through time i.e. during the day less demanding TV-programs (e.g.

cartoons) leave more bandwidth for data transmissions whereas in the evening (sports!) most mobile service users are at home and will probably not use the business data services.

Access to all the internet services like email, ftp or the WWW requires full interactivity. For this purpose the combination with a GSM data upstream channel (9.6 kbit/s) is sufficient. A 38 Mbit/s DVB-T broadcast data channel provides internet access for approx. 6000 users assuming 64 kbit/s downstream rate per user (cf. ISDN) and 10% average workload.

6 The prototype implementation

As already mentioned, the complete system architecture has been realized in a prototype implementation together with the industrial partner Rohde & Schwarz GmbH & Co. KG, Munich (see Fig. 10). With respect to component oriented software engineering, we used formal description techniques like SDL and VHDL for prototyping [2].

For the demonstration we have realized an information service based on the enhanced data casting concepts described in Sections 3.3 and 4.1. to broadcast HTML pages to the users using proxy caches. This service has been enhanced with an implementation of an interaction channel for lightweight interaction based on the Short Message Service (SMS) of GSM. In addition we have realized a prototype of an intelligent router for GSM data connections. Currently we are working on the integration of GPRS in our prototype system to have a packet based interaction channel.



Fig. 10: The prototype system

The prototype has been presented on several international fairs, e.g. Digital Signs/SYSTEMS'99, Munich, and IBC'99, Amsterdam, and has been integrated in the Bavarian DVB-T field trial in Munich.

7 Conclusions

In our paper we have presented a system concept for a multiservice network architecture that bases on digital broadcast networks. The described system concept allows the efficient use of available radio bandwidth for all kinds of mobile information services.

Information services show quite broadcast oriented characteristics (multi user access to information servers, download of files). Therefore our system concept addresses the requirements of different services and provides different solutions especially adapted to the needed transport characteristics. For our multiservice system we have defined components to support:

- Simple data broadcast (IP based) services
- Enhanced data casting services (TCP based)
- Information services with local personal interactivity
- Information services with lightweight personal interactivity
- Full interactive services

In order to support a flexible service development all system components have been designed in a modular way with well defined interfaces. In this way all components could be used separately or in other combinations for various service systems.

The prototype implementation of the system has shown that digital broadcast networks complement the existing radio network infrastructures very well to provide reliable broadband services to the mobile users. Especially the Digital Video Broadcast (DVB) system is very well suited for the presented system concept. The example scenarios and the appropriate traffic estimations emphasize the feasibility of our approach.

8 Acknowledgements

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