Broadband Internet Access over Digital Video Broadcast (DVB)*

Peter Sties, Jörg Eberspächer, Wolfgang Kellerer, Bernhard Kreutzer, Holger Reichel
Munich University of Technology (TUM), Arcisstr. 21, 80290 Munich, Germany

Günther Zurek-Terhardt
Rohde & Schwarz GmbH & Co KG, Mühldorfstr. 15, 81671 Munich, Germany

Abstract. The ongoing technical progress of communications networks results in a convergence of traditionally separated networks and services. One result of this convergence is the use of digital broadcast networks (e. g. terrestrial digital video broadcast DVB-T) as access networks not only for video, but also for data services, e. g. internet/WWW. Our paper presents a system for sending HTML pages over a DVB-T network. To enable the access of WWW services for mobile users, the part of the bandwidth in the DVB-T system currently not occupied by television channels can be used for data transmission. To allow the flexible and efficient development of new services, the system design has to support the reuse of components and a systematic tool-assisted implementation. In detail our paper describes the building block oriented design of the entire system, the developed transmission method to transfer IP packages over DVB-T and the developed HyperText Push Protocol (HTPP) for the transmission of HTML pages over unidirectional channels. Furthermore, we explain the prototype implementation of the system in soft- and hardware with the use of the specification languages SDL and VHDL.

1 Introduction

The continuous advancement and the associated technical progress of the communication networks lead to tremendous changes of communication techniques. The performance of the individual networks multiplied in the last years. On the one hand, this promotes the efficiency of the services for which the respective network was originally developed. On the other hand, networks can now take over new services for which different networks were originally developed, e. g. telephony over internet or data communication over the cable television network.

In earlier times this development led to the substitution of individual service-specific networks, e. g. the substitution of the telex network by the fax service of the telephone network. But at present, rather a general approximation of the different networks is to be observed, usually called "convergence of networks".

The growing interest in the internet and the increasing mobility lead to a rising demand for new mobile access possibilities to the internet and its services, e. g. in the car. Here, an

* This work was supported by the Bayerische Forschungsstiftung as part of the research consortium "Bayerischer Forschungsverbund Software Engineering (FORSOFT)" in the project C2 „Service Engineering“.

important role plays the radio access. However, the increasing bandwidth requirements encourage the search for new ways that go beyond the abilities of the GSM network. New, more efficient networks, which offer larger bandwidth for internet access like the Digital Video Broadcast (DVB), are promising.

DVB [1] provides the delivery of MPEG-2 transport streams via a variety of transmission media. In the case of DVB over terrestrial radio (DVB-T), mobile receivers can be used. Traditionally the MPEG-2 transport stream contains packets of compressed video and audio data. The compression causes a variable data rate of each TV program because scenes with a lot of motion in the picture are encoded with a higher bitrate than scenes with less motion. In order to get a fixed data rate for the transmission, e. g. 38 Mbit/s, stuffing packets are inserted into the transport stream.

Within DVB, it is possible to carry defined data containers in addition to the audio and video in the MPEG-2 transport stream. These data containers can be used to realize new data services or to carry IP datagrams. There are two possibilities: The bandwidth unused due to the stuffing packets is always available for data broadcasting services and can be used for value added services. Furthermore, full channels can be used for data broadcast. The wide bandwidth allows the realization of new broadband data services.

To investigate these new technologies, we chose a generic service: The transmission of HTML-Pages over DVB-T. This service could be used for a videotext like value added service and also as a broadband interactive service.

2 The component oriented system design

For the design of the system the following requirements were defined:

- Component orientation: The total system should be subdivided into components. These components should be as generic as possible to enable the reusability of the individual components for further systems.
- Interfaces: Well defined interfaces are necessary in order to allow that the individual components can be developed independently from each other.
- In order to keep the development easy and to facilitate the reusability of the components, the design should be based on well-known and common protocols etc. as far as possible.
- Implementation: The specification and implementation of the individual components should be done systematically and with the use of suitable tools.

Considering these requirements the following system concept was developed (figure 1). The system consists of three component layers. In the lower layer, data-packets are inserted in and extracted from the MPEG transport stream. The middle layer provides a push service for HTML pages. To have a most generic interface between these two layers, IP was chosen as the connecting means. The middle layer has two standard HTTP connections to the upper layer. The transmitter side requests the desired HTML pages from the internet or designated WWW servers. On the receiver side, a standard browser can be connected to browse through the transferred pages. The selection of pages to be transferred is supplied to the transmitter in a text file with a list of the desired URLs.

The generic interfaces allow to use standard components in the upper layer and to reuse the described components separately for other systems. The IP-packet Inserter and Reader could also transmit any other kind of data, e. g. emails or software files, by exchanging the HTML push components with any service component which is based on unidirectional IP connections. On the other side, the HTML push components could be used on any other unidirectional IP connection, e. g. on DAB or cable TV.

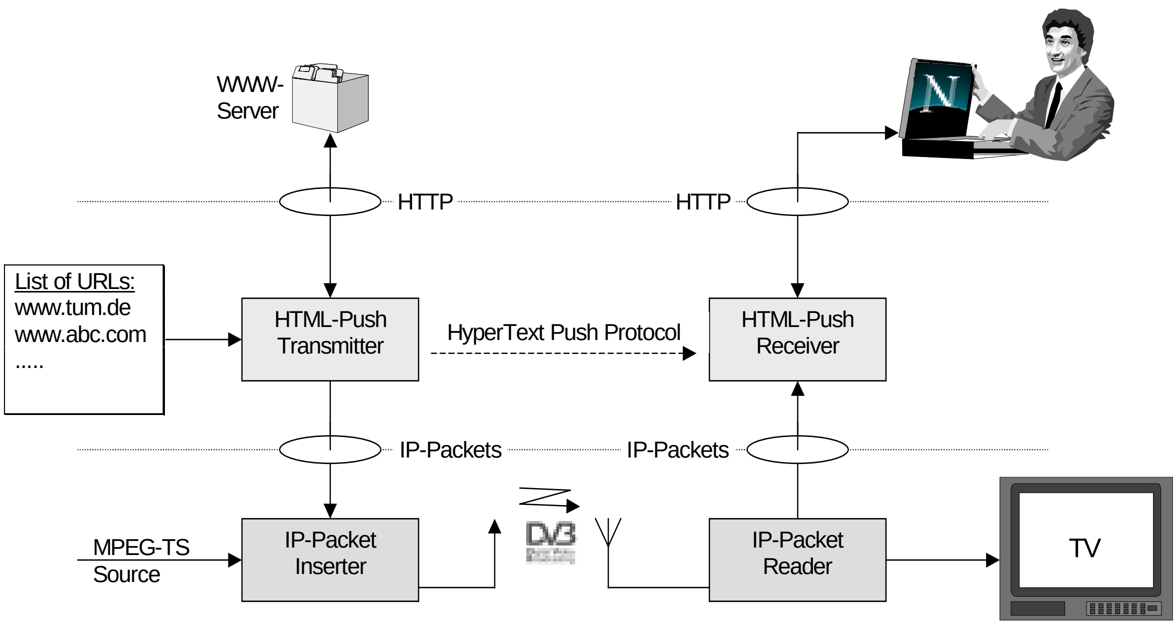

Fig. 1: The components of the system concept

In the following two chapters, we give a more detailed specification of the mentioned components and the way how they were implemented for a prototype system.

3 Broadband Data Broadcasting over DVB-T

The goal was to transmit IP-packets over a DVB channel. Therefore, IP-packets have to be inserted into the MPEG-2 transport stream at the transmitter side and to be read out after the transmission. This is achieved with modified hardware components from Rohde & Schwarz. In this equipment two Field Programmable Arrays (FPGA) are programmed with VHDL to insert IP-packets into or to extract them from the transport stream.

3.1 Description of the transmission system

The whole system is based on open standards like DVB and MPEG-2. The DVB specification for data broadcasting [2] defines four different application areas with different requirements for data transport. For each application area, the way the data is inserted into the MPEG-2 transport stream is described. In our case the "multiprotocol encapsulation" standard was chosen because its data containers (called datagram sections) are optimized for carrying IP datagrams. The mapping of DVB datagram sections into the transport stream is defined by MPEG-2 [3] . Each section carries one IP datagram with a length up to 4086 bytes. The IP packets are received by the IP-Packet Inserter from the HTML-Push Transmitter (see figure 1). In the IP-Packet Inserter, the datagram sections are formed, then fragmented and mapped into transport packets with a length of 188 byte. These packets are inserted into the transport stream by exchanging them for stuffing packets which are already present in the transport stream. In this way the data rate of the stream is not modified, and the video and audio data is not affected.

Each transport packet is labeled with a PID (packet identification number) indicating the type of the data stored in the packet payload. We use the PID 0x001D for packets carrying our datagram sections. The receiver is to detect the packets with this PID and extract them from the transport stream.

The IP-Packet Inserter in figure 1 consists of a PC and a peripheral hardware connected via an enhanced parallel port (EPP). This is a high speed bi-directional parallel interface for PCs. The IP packet interface (see figure 1) is implemented in software on the PC. The datagram sections are also formed and fragmented into transport stream packets by software. When a transport stream packet is ready for transmission, it is sent via the EPP to the peripheral hardware where ten packets can be buffered. If a stuffing packet is detected in the passing transport stream, it is exchanged for a packet from the buffer.

On the receiver side, the hardware is waiting for a packet with the defined PID. If such a packet arrives in the incoming transport stream it is read out and buffered. In the hardware as well, ten packets can be buffered. The received packets are transmitted to another PC, where the received datagram sections are recovered and transmitted to the HTML-Push Receiver.

The data rate of the inserted packets depends heavily on the PC performance. With a 166 MHz Pentium PC, data rates over 5 Mbit/s have been measured. The receiving PC should be faster than the PC at transmitter side so that no packets are lost.

It has to be mentioned that the Inserter and the Receiver hardware are identical, they differ only in the programming of their FPGAs.

Details of the data casting mechanisms and its implementation can be found in [4].

3.2 Implementation using VHDL

The VHSIC (Very High Speed Integrated Circuit) Hardware Description Language (VHDL) is a formal notation for electronic systems. Because of its machine readable and human readable form it can be used for specification, development, verification, synthesis and testing of hardware designs as showed in figure 2.

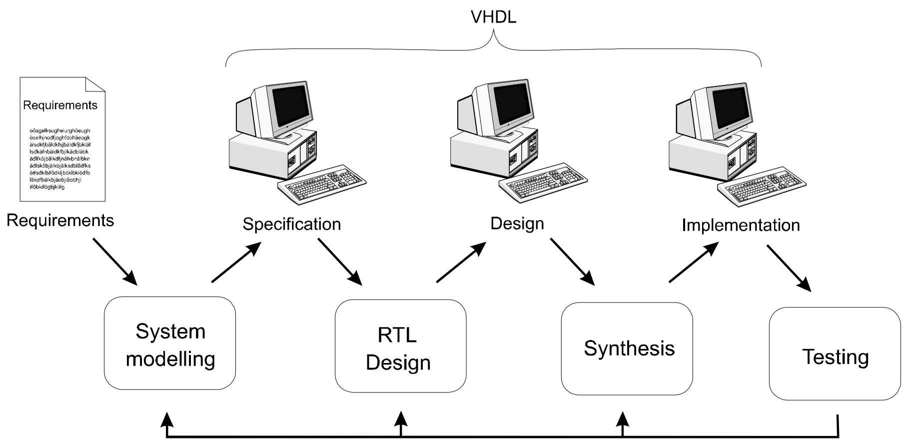

Fig. 2: VHDL system design

The system modeling and the building of a register transfer level (RTL) design must be done by the developer, the synthesis can be run automatically. A RTL design describes a circuit as a set of registers and a set of transfer functions between these registers, and can also be done using VHDL. VHDL allows to describe a hardware design on multiple layers in a very abstract way. The description is independent from the hardware that is finally used. The multilayer architecture of a complex design allows to set the focus on small and clear parts of the whole circuit. Furthermore it is possible to simulate parts of the design in a very early phase. Simulating and testing of small components is much easier than simulating and testing the whole system. In this way mistakes can be detected at an early stage. Another advantageous aspect is that third-party components can easily be incorporated into the design, and new developed components can be used later on in further designs.

The functionality of the IP-Packet Inserter and the IP-Packet Reader have completely been developed with VHDL. Specific attention was given to a modular design to enable reuse. Thus some identical components could be used in the Inserter and in the Reader as well.

4 Browsing the Web anywhere

Like all other services in the internet, the WWW connection is client – server based. The browser (client) sends a request to the web server which returns the data in case of success. The format of request and response is defined in the HyperText Transfer Protocol (HTTP). As mentioned in section 2, it should be possible to use a standard browser on the receiver side to browse through the transferred pages. Because of the unidirectional character of the DVB system, the browser cannot send requests in order to load the designated web pages. Therefore a proxy-server functionality had to be integrated into the HTML push receiver. Now the browser can send the requests to this proxy.

Looking at the transmission of HTML pages over the unidirectional channel, one can see that the push principle has to be used: information is supplied at the transmitter side and is then transferred to the receiver. To make sure that the data is present at any time and can easily be updated if necessary, the information pages are sent continuously in repeated transmission cycles.

4.1 The HyperText Push Protocol (HTPP)

A proxy normally acts as an intermediary in the communication chain between browser and server in order to reduce the loading time of HTML pages as well as the net load. By managing and caching the requests together with the matching responses, it can send available pages out of its cache in case of another request for cached pages. Because the proxy-cache of our system receives data from servers without having sent a request before, it needs the information about the origin of the data. Only with that information the proxy can react exactly to the requests sent by the browser. As no existing protocol is providing such a functionality, we developed a new one named HyperText Push Protocol (*HTPP*) [5]. The *HTPP* can be seen as an additional header field in front of the HTTP header. In the OSI reference model, a protocol that provides information as described above, lies in a layer between the HTTP and the transport layer (e. g. TCP/IP). Figure 3 shows the OSI based communication model of the used components.

The transmitter requests the HTML pages, which were selected by the service provider for transmission, over an HTTP connection from the (internet) web servers, appends the *HTPP* information and sends the data over an unidirectional channel to the receiver. There, the *HTPP* information is separated, and the pages now containing only HTTP information are stored. With the additional *HTPP* information, the receiver can now handle the conventional HTTP requests from the browser.
In detail, the *HTPP* features the following functions:

- clear assignment of the pushed HTML pages to the origin servers by transmitting the complete URL (Uniform Resource Locator)
- possibility for the receiver to recognize transmission errors
- maintenance of the actuality of the data at receiver side
- flexible extension possible by variable header length

A detailed description of the *HTPP* is given in [5].

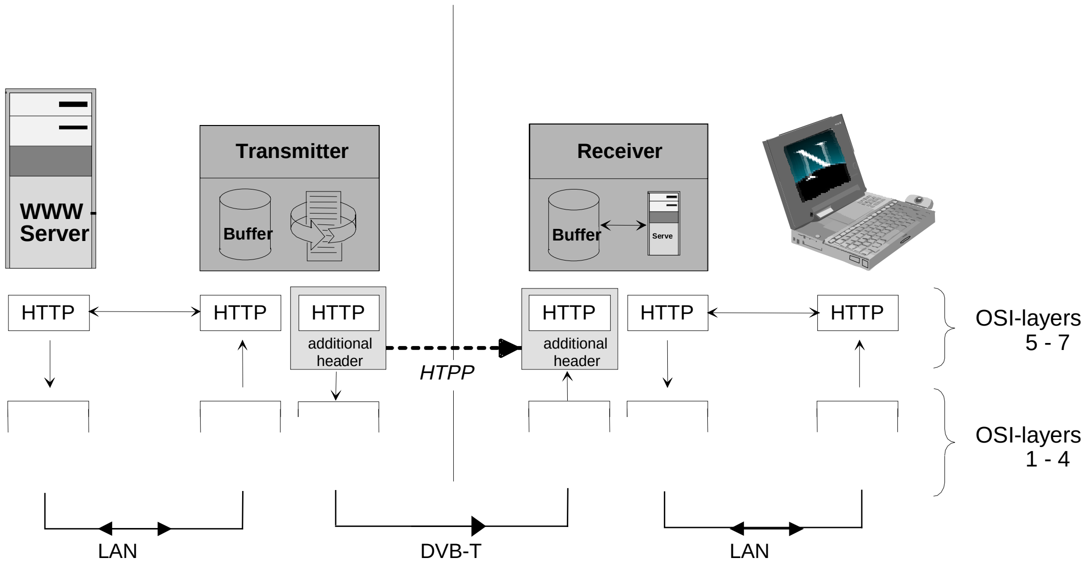

Fig. 3: OSI communication model of the system

4.2 Implementation using SDL

SDL (Specification and Description Language) is a formal language for system specification based on finite state machines. With SDL the behavior of systems along with their data structures can be described. Large systems can be divided into smaller ones by clear structuring elements of the language. The communication between the state machines in form of sending signals describes the dynamic behavior of the entire system. SDL is standardized by the ITU (International Telecommunication Union) [6] and allows an object oriented attempt to support the reusability of parts of a system by inheritage.

SDL was chosen for the prototype implementation of the HTML-Push Transmitter/ Receiver to ensure a systematic and formal software development.

5 The prototype system

The system concept described above has been realized in a prototype implementation to demonstrate its feasibility (figure 4). On the sender side two Pentium PC are responsible for the preparation of WWW pages and the insertion of data packets into the transport stream, respectively. The service content provider is represented by a configuration file in which URLs of WWW sources are stored. The HTML-Push control retrieves these pages via a connection to the internet with the HTTP protocol and transmits them to the second PC in the *HTPP* format over a LAN connection. This PC is connected to the IP-Packet Inserter hardware, which includes the developed FPGAs. An MPEG stream generator provided by Rohde & Schwarz supplies our system with video sequences including stuffing packets.

The receiver side, which represents a mobile user system, is analogous in most parts to the sender. A PC receives the data packets from the IP-Packet reader and transmits them to the *HTPP* receiver. The video sequences can be watched on a conventional TV set which is connected via a Rohde & Schwarz stream analyzer acting as a set-top-box to the IP-Packet Reader. The *HTPP* receiver stores all incoming WWW pages in its proxy cache. Any conventional WWW browser can access the information inside this proxy without the need of modifications. An integration of the receiver hardware even in a car radio seems to be feasible as most of the work is done within only two FPGAs.

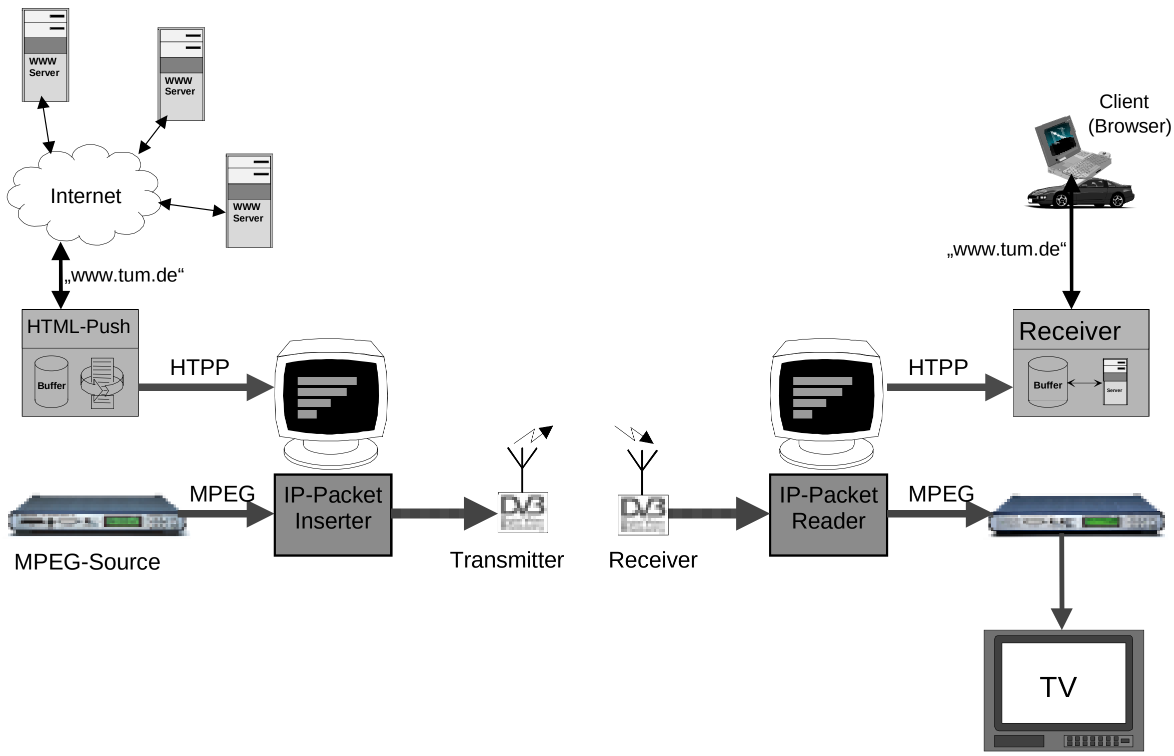

Fig. 4: The prototype system

6 Conclusion and Outlook

In our paper we have presented a flexible system for broadband access to internet services like WWW over the terrestrial radio broadcast network DVB-T. The large bandwidth provided by DVB-T in combination with our information casting concept allows to reach the mass of mobile users with up to date information services. In order to make the transmission system transparent for the applications, we have used the IP protocol stack for the interconnection of the system components.

This system concept already enables lots of applications for mobile users, e. g. actual traffic reports, multimedia tourist information or premium-rate services like actual stock quotes on the screen of your car radio.

With respect to the desire of users to request certain pieces of information that are not present in the content pre-selected by the content provider, the system can be complemented with a return channel. This will provide interactivity to mobile users accessing multimedia services over wireless networks. Mobile networks like GSM can realize the interactivity channel in the enhanced system, which is currently investigated at our institute.

This enhancement of the system allows a whole set of new applications from individual route maps for car drivers to a fully interactive internet access everywhere. The combination of broadband radio networks like DVB-T with interactive narrowband networks like GSM seems to be very promising for realizing multimedia interactive data services.

References

[1] DVB – Digital Video Broadcasting Homepage. http://www.dvb.org

[2] European Telecommunications Standards Institute (ETSI*). Digital Video Broadcasting (DVB); DVB specification for data broadcasting*. European Standard EN 301 192 v1.1.1, December 1997.

[3] ISO/IEC 13818-1: *Information technology – Generic coding of moving pictures and associated audio information: Part 1: Systems, Recommendation H.222.0*, International Standard.

[4] H. Reichel. *Datenübertragung im MPEG-2 TS für multimediale Informationsdienste über DVB*. Diploma thesis at the Institute of Communication Networks, Munich University of Technology, February 1999.

[5] B. Kreutzer. *Entwicklung einer HTML Pushdienststeuerung zur unidirektionalen Übertragung von WWW-Seiten*. Diploma thesis at the Institute of Communication Networks, Munich University of Technology, December 1998.

[6] ITU-T Recommendation Z.100: *Specification and Description Language (SDL)*, ITU-T, Geneva, 1993.