An Interactive DVB-T Platform with Broadband LMDS Uplink

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ABSTRACT

Contemporary DTV technologies introduce the concept of interactivity to traditional TV broadcast services, provided that a data return channel exists. This paper proposes a wireless access network which is a result of the convergence of wireless data network technologies and digital broadcasting. The proposed network, which is being implemented in the frame of the EU-funded MAMBO IST project, can offer digital television and fast Internet access to stationary users, utilizing DVB-T technology for broadband downlink, while the uplink is based on an LMDS network.

I. INTRODUCTION

Telecommunications and digital broadcasting are two sectors which, have until recently followed parallel paths, occupying separate fields at service provision level. Broadcasting deals with "point-to-multipoint" connections and aims at distributing broadband multimedia content to a large number of end users. Conversely, modern digital telecommunication systems are being developed under the philosophy of "one-to-one" connections such as personal audiovisual communications and peer-to-peer data exchange, including access to Internet.

There are several ways in which the strengths and weaknesses of these two types of network can complement one another, resulting in novel bidirectional networks, combining interactivity with provision of broadband multimedia services. The concept of interactive broadcasting is based exactly on this philosophy.

The network proposed in this paper has been developed in the frame of the IST project MAMBO (Multi-Services Management Wireless Network with Bandwidth Optimisation / IST-2000-26298). It combines the DVB-T technology with existing cellular networks (Local Multipoint Distribution System - LMDS) to offer interactive digital television services through terrestrial networks to stationary users along with high-speed data services. By using DVB-T for the downlink and LMDS for the uplink, an asymmetrical access network is created which takes advantage of the main characteristic of platforms providing multimedia content: The amount of data retrieved by the end user is huge compared to that which is sent back to the network, mostly in the form of requests or acknowledgements [1]. The DVB-T downstream comprises a CBR (constant bit-rate) multi-megabit MPEG-2 bouquet able to carry DTV programs along with IP data.

Until now, commercially available access to data services through a DVB network has been restricted to the DVB-Satellite/PSTN configuration, where the end user receives the data from a satellite dish antenna and sends requests and acknowledgements through the analog telephone network. However, such a configuration has several drawbacks:

- it needs special equipment and installation for satellite reception,
- the poor performance of the PSTN line also restricts the downlink rate,
- the user must go through the connection setup process every time he wants to access the network, and
- the high round-trip delay times significantly decrease the overall data throughput.

In contrary, the DVB-T implementation allows for easy and reliable reception of the digital stream through a standard UHF antenna. Moreover, the LMDS technology ensures constant connection to the uplink network, providing the capability of anytime broadband access. Thus, the uplink can be used not only for Internet access, but also for IP data transmission back to the service provider/TV station, realizing a truly interactive television service [2].

In addition, the platform implemented in the frame of the MAMBO project extends the concept of interactivity to design a feed back loop bandwidth optimisation mechanism in order to collect information concerning the picture quality at the end-user terminals. This information is sent back to a bandwidth allocation module integrated in the service provider platform, which allocates the optimum amount of bandwidth to each service, including television programs and IP data provision.

In such a scenario, the LMDS return channel is essential not only for the proper operation of the platform as an IP data network, but also for the transport of quality-of-service data stemming from the end users to the bandwidth allocation module.

II. OVERALL NETWORK CONFIGURATION

The proposed architecture is a solution for service providers and mobile operators who demand a flexible and cost-effective method for managing compressed digital services while providing end users with interactive IP-based services. At the service provider site, the operator is able to select specific services of interest, from a large number of TV and IP services, locally generated or arriving at its site via satellite or terrestrial.

The overall system configuration is illustrated in Fig.1. The use of the DVB-T platform for the downlink provides an extended coverage area (macrocell) within which the client terminals can operate. The return channel is provided by an LMDS cellular network organized in cells inside the DVB coverage area. The LMDS subsystem is based on the IEEE 802.11 specification for multicell wireless data networks. The cell main nodes (Base Stations) feed the return data (requests, acknowledgements, QoS data) back into the system kernel. Fig. 1 shows the configuration for a single-cell reverse link, but in a wide-area implementation a multicell structure can be adopted without significant technical modifications.

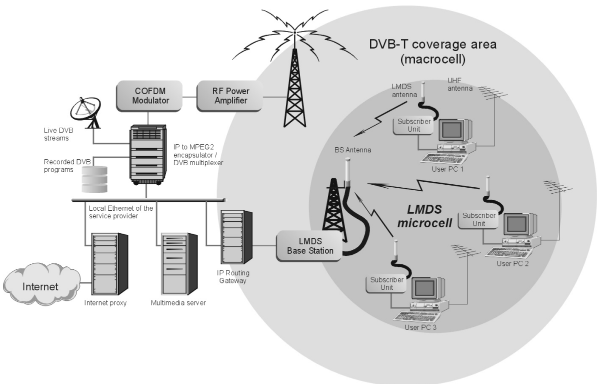

Figure 1: General System Configuration

III. SERVICE PROVIDER ARCHITECTURE

The kernel of the platform, installed at service provider level, consists of the MPEG-2 multiplexer and the DVB transmitter along with the local IP network. An LMDS Base Station (BS) collects the requests and acknowledgements stemming from the end user PCs and sends them as IP packets to the IP Routing Gateway. The latter routes the datagrams to the local Ethernet, prohibiting any reverse traffic i.e. not allowing IP data destined to the users to go through the Base Station. User data sent to the TV service provider (e.g. requests, votes or other interactive data) reach their destination within the Ethernet at the service provider site. If these datagrams contain requests for external hosts, they are routed to the Internet through a dedicated proxy.

IP packets destined for the end users, originating either from local servers or from the Internet, are collected by the IP to MPEG-2 gateway, which encapsulates the IP data in a DVB-compliant MPEG-2 Transport Stream. This stream is fed into the multiplexing kernel and is combined with DTV programs, either live or pre-recorded to form a constant bit-rate DVB bouquet. The final multiplex is the input to a COFDM (Coded Orthogonal Frequency Multiplexing) modulator and power amplifier and is transmitted within the UHF band according to the DVB-T standard [3]. The maximum useful rate of the digital transport stream ranges from 4.98 up to 31.67 Mbps and depends on the modulation parameters used (constellation, convolutional code rate, guard interval)

IV. CLIENT CONFIGURATION

At the end user side, the multimedia terminal is integrated into a standard PC, equipped with the appropriate hardware modules. In the future, this terminal is possible to be easily implemented as a stand-alone set-top box. A digital terrestrial television receiver integrated in a single standard PCI card is the interface of the end user's personal computer to the DVB-T network. This interface collects the RF signal from a standard UHF antenna and allows easy access to TV programs and IP services encapsulated inside the MPEG-2 transport stream. The card is configured to extract from the Transport Stream the IP data destined for its own MAC address, and to reassemble the IP datagrams, which are in turn delivered to the TCP/IP stack of the operating system for further processing.

The user's PC is connected to an LMDS Subscriber Unit (SU) through its standard 802.3 port. The point-to-multipoint LMDS uplink is based on CDMA technology, utilizing the Frequency Hopping technique, supporting a nominal data rate of 3 Mbps. The CDMA/FH system operates in half duplex mode at the frequency of 2.4 – 2.4835 GHz unlicensed Industrial, Science, Medical (ISM) band. Digital modulation follows the Gaussian FSK (GFSK) scheme, at 2,4 or 8 levels, conveying 1,2 or 3 bits per symbol.

Utilizing the reverse channel based on this link, end users are able to access broadband multimedia services, such as video/audio-on-demand and videoconferencing along with fast connection to Internet. In the downlink, all these interactive services are multiplexed with MPEG-2 digital television programs.

V. PERFORMANCE MEASUREMENTS

In order to test and evaluate the proposed configuration, a small-scale testbed with three client PCs was implemented within the campus of NCSR "Demokritos". The MPEG-2 multiplexer was configured to retransmit two DTV programs stemming from a satellite receiver, along with the IP stream produced by the gateway and its output rate was adjusted so that it does not exceed the total capacity of the COFDM transmitter. The OFDM carriers were modulated according to the 64QAM scheme, the convolutional code rate was set to 5/6, and the guard interval to 1/8 of the OFDM symbol. These settings ensure a maximum useful rate of 27.65 Mbps. Omnidirectional antennas were used operating at medium to low power levels (1W and 160mW EIRP for the DVB-T transmitter and the LMDS devices respectively). The three wireless users were distributed within a range of 100m from the service provider antennas.

The proper configuration and set-up of the network was at first stage verified through plain ICMP ECHO requests ("ping") sent from the user PCs to the IP Routing Gateway. A series of ping round-trip time measurements gave an average value of 40 msec. Such a relatively high delay is mostly due to the processing time and large buffers within the DVB encapsulator and multiplexer.

In order that this delay is compensated for, a relatively large TCP window must be chosen between the end-user and the server from which the data was retrieved. This is a common technique in all networks characterised by high delay times, such as the satellite networks [4]. The IP throughput measurements were performed on a standard FTP file retrieval procedure between one of the three wireless users and a dedicated FTP server, running on the multimedia server of the Ethernet backbone. Increasing the window size in steps of 4KBytes up to the limit of 64K, the useful throughput of the IP service varies from 200 kbps to 6.5 Mbps. This relationship is shown in Fig. 2.

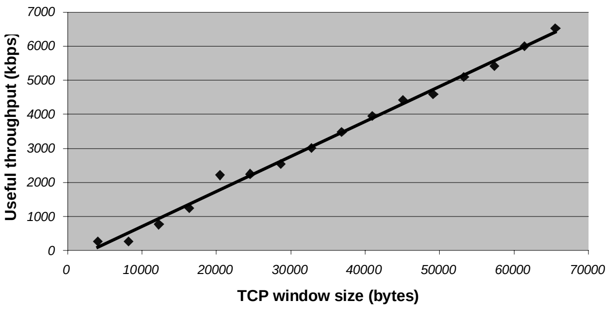

Fig. 2. IP Throughput for a single user vs. TCP window size

In order to conduct measurements in a multi-user environment, the TCP window is set to a typical value of 16K used in most TCP applications. The system was tested under the simultaneous load of three different users which view the DTV programs on a video monitor while initiating an FTP file retrieval session to a local server (70MB single file transfer). Although the system is configured to offer fast Internet access to the end users via the Internet proxy connected to the service provider network, a connection to a remote site would not provide a guaranteed bit rate and thus would be unsuited for measurements of downlink performance.

As shown in Fig. 2, a TCP window size of 16K provides about 1.7 Mbps of useful downlink rate to each user. Given that the total available downlink for IP services can reach more than 20 Mbps (i.e. the total bandwidth minus the bitrate of the digital television programs), it is obvious that such a capacity cannot be utilized by a single user. A multi-user environment ensures more efficient bandwidth utilization, as shown in Fig. 3. These graphs, which are aligned in time, show the bit rate utilized by each client. User 1 begins downloading first -and thus completes the session first-, followed by User 2 and 3. The last graph shows the aggregate throughput, i.e. the total IP load which passes through the DVB gateway.

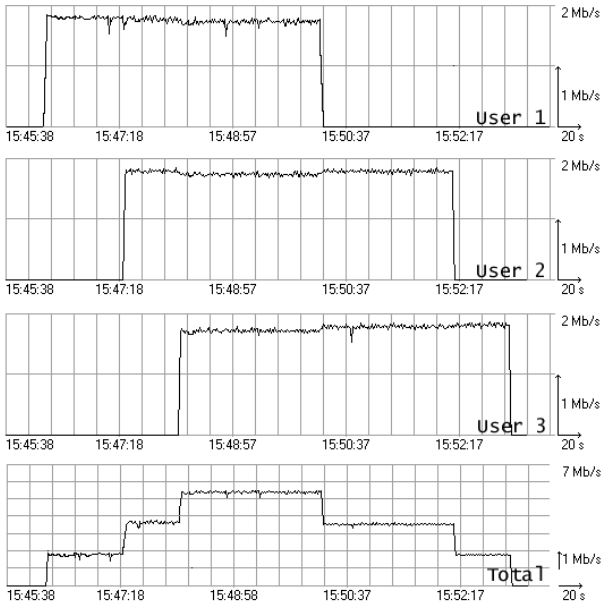

Fig. 3. Three users retrieving data successively

It should be noted that the three users do not share a certain bandwidth, but their bit rates are added to the total throughput (until the maximum rate at the output of the DVB gateway is reached). This is because their useful rate is not restricted by the downlink capacity, but by the round-trip delay of the TCP datagrams.

VI. CONCLUSION

This paper illustrated an interactive DVB-T platform, utilizing an LMDS network for the return channel. This configuration implements a truly interactive television service, combining high-quality digital television with broadband bidirectional data services, including fast access to Internet. The efficiency of the IP service was evaluated along with the provision of DTV programs, and the behaviour of the platform under load from multiple users was verified. Configurations like the one proposed in this paper which enable for broadband communication at the uplink, allow the end user not only to receive, but also to send bandwidth-demanding video and multimedia content back to the service provider. As stated above, this specific configuration will be used in the MAMBO project not only to implement a truly interactive platform, but also to provide a physical route for the feedback QoS data.

REFERENCES

[1] G. Gardikis, E.Pallis, A.Kourtis, "Beyond 3G: A Multi-Services Broadband Wireless Network with Bandwidth Optimisation", in Proceedings of VTS/IEEE Intl. Symp. on 3G Infrastructure and Services, Athens, Greece, July 2001, pp.176-179

[2] E. Pallis, A. Kourtis, A. Alexandridis, G. Pantos, Ph. Constantinou, "Provision of Internet and digital MPEG-2 programmes via a wireless broadband network", in Proceedings of 4th ACTS Mobile Communications Summit, June 1999

[3] ETS 300 744: *Digital Video Broadcasting (DVB): Framing structure, channel coding and modulation for Digital Terrestrial Television (DVB-T)*, ETSI, 1997

[4] H. Clausen, H.Linder, H., B. Collini-Nocker, "Internet over Direct Broadcast Satellites", IEEE Communications Magazine, June 1999