Reverse Path Technologies in Interactive DVB-T Broadcasting

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ABSTRACT:

The convergence of different networking infrastructures and the integration of fixed, mobile and broadcasting technologies is the new era in telecommunications. This paper describes the design, implementation and testing of a network architecture able to integrate DVB-T broadcasting technology for the downlink with GSM and LMDS access technologies for the uplink. It provides fast access to IP services and digital television to residential and mobile users and it will be used as a demonstration platform for the EU-funded MAMBO-IST project.

I. INTRODUCTION

Within the past few years, many types of network technologies have been developed. The main reason for that course is the requirement of spectrum efficiency. Various digital radio technologies have emerged, optimized for specific and individual services. However, existing and emerging multimedia applications exhibit challenging new requirements in terms of symmetry, interactivity, mobility and real-time and multicast communication.

The integration of these technologies provides the opportunity of designing an efficient and fast network infrastructure, for providing end users with a diversity of multimedia and IP services.

MAMBO (Multi-Services Management Wireless Network with Bandwidth Optimization IST-2000-26298) project aims towards the convergence of networking infrastructures and the integration of fixed, mobile and broadcasting technologies. The project objective is to merge DVB-T (Digital Video Broadcasting–Terrestrial), LMDS (Local Multipoint Distribution System) and GSM (Global System for Mobile Communications) technologies in an integrated and seamless environment. MAMBO project will develop, implement and assess a universal, open and scalable platform that manages the distribution of high quality interactive multimedia DVB / IP services through a terrestrial access network, to mobile and residential end-users by an optimal allocation of the allowable bandwidth. To fulfill this, a distributed feedback loop bandwidth optimization mechanism will be implemented, which is able to adapt, in real time, the bit rate of the multimedia services, without significantly degrading the service quality.

This paper presents the design and implementation of a wireless terrestrial network infrastructure, which conforms to the requirements of the MAMBO platform and will be used for the final demonstration of the project's concept. The performance of the network is evaluated for the provision of high speed data services to residential and mobile end-users, using various types of reverse path channels. To achieve this, a DVB-T beam is used in the downlink, while for the uplink two different reverse path configurations are tested and evaluated: an LMDS network addressed to residential end-users and a GSM network addressed to mobile end-users. The network architecture is highly asymmetric, as the downlink is a high bit rate DVB-T beam and the up link is a lower bit rate channel based either on LMDS or GSM technologies. Concerning mobility, which is an important feature of the proposed network, it is supported by DVB-T in the downlink (due to the inherent capability of COFDM modulation to reject delayed replicas of the same signal) and GSM in the uplink. The proposed network architecture is able to provide data, and IP services as well as TV programs, all in the MPEG-2 transport stream. The paper describes the implementation and testing of the network and performance evaluation measurements are reported. These are very useful to define the limits of the proposed network, in order to demonstrate the ultimate objectives of the MAMBO project, i.e. the implementation of a distributed feedback loop bandwidth optimization mechanism that is able to adapt, in real time, the bit rate of the multimedia services.

II. OVERALL NETWORK CONFIGURATION

This network architecture is the solution for the ISP (Internet Services Providers) and Broadcasters who want to provide a bouquet of services to their clients with high availability, flexibility and speed. These services include digital television programs with the option of interactivity (due to the existence of the reverse path) and Internet services.

The proposed network configuration is illustrated in Fig.1. The network consists of two main modules. The reverse path reception module handles the acknowledgements and the requests from the end user and routes them properly. The multiplexing module involves the multiplexer and the downlink channel. It is responsible for encapsulating the IP data into an MPEG-

2 stream, multiplexed with video and audio and then transmitting the created MPEG-2 stream, according to the DVB-T standard, to the end user.

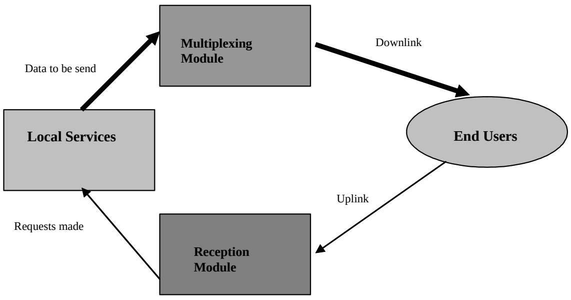

Figure 1 Network modules

The overall system configuration is illustrated in Fig.2. The use of the DVB-T platform for the downlink provides an extended coverage area (macro cell) within which the client terminals can operate. The reverse path is implemented with the use of two different access network technologies, GSM and LMDS. Additionally, a narrowband return channel based on common PSTN lines is included for comparison reasons. The integration of these technologies extends the capabilities and the suppleness of the proposed network.

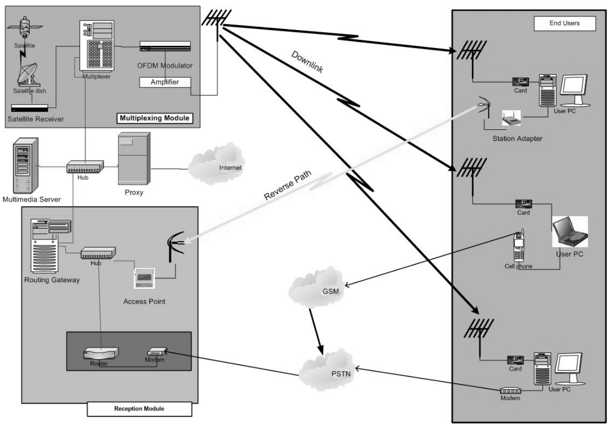

Figure 2 General network architecture

III. SERVICE PROVIDER ARCHITECTURE

A. Reverse path reception module

This module is responsible for providing the appropriate links from the end-users to the service provider. The module consists of three parts: the combination of a router and a modem that allows the connection of users through a GSM mobile phone or PSTN modem, an Access Point, which offers connectivity to LMDS end-users, and finally a routing gateway. The RS-232 port of the modem is connected to the serial port of the router, which is responsible for controlling the connection, assigning of a static IP address to the user, and routing properly the IP packets to the routing gateway. The end-user connects to the modem and is assigned automatically an IP (e.g. 10.0.0.199) and using the router's default gateway IP (i.e. 10.0.0.192) is able to send data.

The Access Point is the base station of the LMDS point-to-multipoint network. It 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 in the frequency of 2.4 – 2.4835 GHz unlicensed Industrial, Science, and Medical (ISM) band. The bit rate has a fall back of 2 and 1 Mbps. The Access Point collects the requests and acknowledgements stemming from the end user PCs and sends them as IP packets to the IP Routing Gateway.

The IP Routing Gateway acts as an intermediate between the ISP backbone and the end users' network. It is equipped with two network interfaces. The first one, connected to the users' subnet, is assigned a dummy IP address (e.g. 10.0.0.1) and the other one, connected to the service provider's local Ethernet, is assigned a real IP address (143.233.44.71). User data is received by the 10.0.0.1 interface. A NAT (Network Address Translation) running on the routing gateway substitutes the source IP and port by the gateway's IP and the appropriate new port number. Then, the IP data reaches destination through the Ethernet Network of the service provider. If data from external hosts (Internet) is requested then the requests are serviced through the Internet Proxy server.

B. Multiplexing module

The multiplexing module is responsible for capturing the IP data destined to end-users and encapsulating them into a DVB compatible MPEG-2 transport stream. Its main components are the Multiplexer and the COFDM modulator. The Multiplexer receives two inputs: one that contains Digital TV programs (live streams received from a satellite bouquet or pre-recorded) and the second that contains the IP datagrams. The multiplexer combines the two inputs, thus creating the final constant bit-rate DVB bouquet, to be transmitted to end-users. This transport stream is the input to a COFDM Modulator (Coded Orthogonal Frequency Multiplexing). The produced signal is amplified by a power amplifier and transmitted in the UHF band according to the DVB-T standard. The maximum useful rate of the digital transport stream ranges from 4.98 up to 31.67 Mbps, according to the modulation parameters (constellation, convolutional code rate, guard interval).

The Multiplexer is a PC where IP packet capturing/filtering/multiplexing software runs and monitors the local Ethernet for IP traffic. Every IP packet that matches the filter, which is defined by the operator, is captured and stuffed into the MPEG-2 transport stream. An IP to MAC association table is provided in order to correctly associate the IP of the end-user with the receiving card's MAC address. In this way, every user can quickly capture -from the whole stream-only the packets that are destined to him.

IV. CLIENT CONFIGURATION

The client part is a standard PC, equipped with the appropriate hardware and software modules. Two different types of client PCs were used, depending on the reverse path technology. The first type is addressed to static (residential) users. The PC is connected to an LMDS Station Adapter through its standard 802.3 Ethernet port. The station adapter is associated and communicates with the Access Point at the service provider's site. The second type is addressed to mobile users. In this case, the PC is connected through an RS-232 Serial cable with the GSM standard compatible mobile phone. The mobile phone is able to support data connections at rates up to 9600 bps.

Common hardware in both types is a digital terrestrial television receiver (DVB-T), integrated in a single standard PCI card. This receiver is recognized by the operating system as a network device. Data extracted from this card are either IP datagrams used for IP applications or MPEG-2 data, which are further used by appropriate software to decode and display the video on the PC's screen. In the first case, the DVB-T interface card receives the RF signal from a standard UHF antenna and demodulates it, in order to retrieve the 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.

V. PERFORMANCE MEASUREMENTS

In order to test and evaluate the proposed network architecture, a testbed was setup within the campus of NCSR "Demokritos". The testbed's usage was twofold : (a) to demonstrate the provision of Live TV programs re-broadcasting and Fast access to Internet (2 Mb/s) (b) to measure the performance of the network for the provision of IP based services, in terms of network throughput.

Referring to figure 2, the multiplexer was configured to create a DVB bouquet comprised of a live TV program, whose source was a RAI program received from satellite Hot-Bird-2, at 13° East at 11.804 GHz. The Ethernet backbone of the service provider was connected to the IP input of the multiplexer to allow the encapsulation of IP datagrams into the transport stream. This transport stream was fed to a COFDM modulator through an Asynchronous Serial Interface (ASI). The RF output of the COFDM modulator was fed to a power amplifier that raised the emitted power to 1W, which was radiated in channel 36 (580-598 MHz) in the UHF band, through a suitable omnidirectional antenna.

Two types of end-users were considered in the testbed, a mobile and a static. The first type uses a GSM uplink channel at a speed of 9,6 Kbps. A mobile end-user was installed in a car, which was moving at a low speed (20 Km/h) into Demokritos' campus and at distances up to 100 meters from both sides of the transmitting antenna. The modulation scheme in the COFDM modulator was set to QPSK, the convolutional code rate to 5/6, and the guard interval to 1/8 of the symbol. These settings ensure a useful rate of 9.22 Mbps. Initially, the provision of digital TV programs was tested, when the car was static (at a distance of 100 m from the transmission point) and when moving. In the first case, no picture pauses were observed. In the second case a few picture pauses could be observed, but they were not annoying. It was also verified that the mobile end-user could serf on the Internet. However, the achieved bit rate could not be measured because there are other bottlenecks along the information flow, beyond the proposed network.

The IP throughput measurements were performed on a standard FTP file retrieval procedure between the mobile end-users and a dedicated FTP server, running on the multimedia server of the Ethernet backbone in the service provider. A graphical representation of the throughput for static and moving car is shown in figures 3 and 4, respectively.

Figure 3 Static GSM User Throughput

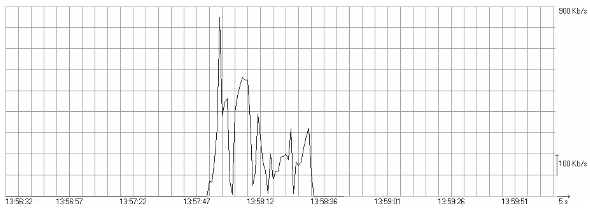

Figure 4 Mobile GSM User Throughput

From figure 3 it can be deduced that a mobile user with a GSM cellular phone is able to achieve a throughput of about 430 Kbps, when being still at a specific point during the ftp procedure. In case that the user is moving, the throughput is not constant but varies between 500Kbps and 30Kbps, resulting an average of 150Kbps (Fig.4). These bit rates are much higher than those achieved when both the up and downlink are based on GSM, resulting a maximum throughput of 9.6 Kbps. The above measurements were taken with the TCP window size of the operation system set at the default value of 16KBytes. It was also verified that the throughput remains the same for TCP window size up to 64 Kbytes. This is due to the relative low bit rate channel in the reverse path.

Another set of measurements were performed for a static (residential) end-user, installed at a distance of about 100 m from the transmission point, within the campus. The reverse path link was implemented using an LMDS network, offering an uplink of maximum 3 Mbps. The transmitted power was 160 mW EIRP with omni-directional antennas of 6 dBi gain. For static users an additional return channel (based on standard PSTN lines, at the speed of 33,6 Kbps) was also considered for comparison reasons. The COFDM modulation scheme was set to 64-QAM, the convolutional code rate to 2/3, and the guard interval to 1/16 of the symbol. These settings result a maximum useful rate of 23.42 Mbps.

The achieved useful bit rate allows the re-broadcasting of two digital TV programs along with IP services. No picture pauses were observed during the reproduction of the TV programs. Internet access was also feasible.

Next, the IP throughput was measured using an ftp file retrieval procedure. As the LMDS offers high bit rate in the reverse path, the TCP window size has a significant effect on the throughput. The maximum throughput was achieved for a window size equal to 64Kbytes, which is the largest allowed by the operating system. Under these conditions, the measured throughput in the downlink was about 7 Mbps, as can be verified by figure 5. During this ftp procedure the bit rate in the uplink was around 160 Kbps.

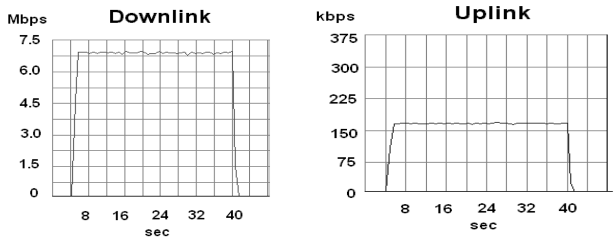

Figure 5 LMDS User Throughput in the downlink and uplink

For comparison reasons, figure 6 shows the graphical representation of the throughput of a user, which uses a common PSTN line of 33.6 Kbps. It is easily verified that the achieved throughput is 1.7Mbps. The TCP window size was set to 64 Kbytes.

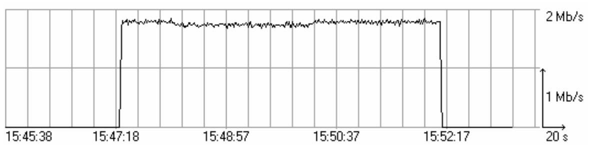

Figure 6 PSTN User Throughput

VI. CONCLUSION

This paper presents the design, implementation and performance evaluation of a wireless terrestrial network infrastructure, based on a DVB-T technology downlink channel. A couple of reverse path technologies are investigated and implemented, the former based on GSM technology, addressed to mobile end users and the latter based on LMDS, addressed to static end users. Furthermore, these two technologies differentiate in the bit rate offered in the uplink, the first being narrowband and the second broadband. It is shown that the proposed network offers a throughput of 430 Kbps to a mobile end user and 7 Mbps to a static user. The re-broadcasting of digital TV programs along with fast access to Internet was also successfully tested.

This infrastructure will be used for the final demonstration and field trials of the IST funded project MAMBO. More specifically, it will be used to demonstrate the convergence of DVB-T, LMDS and GSM technologies in an integrated and seamless environment. Furthermore, to demonstrate in real conditions and measure the performance of a universal, open and scalable platform that is able to optimally allocate the allowable bandwidth, through a distributed feedback loop bandwidth optimization mechanism, which is able to adapt, in real time, the bit rate of the multimedia services.

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