The use of a DVB-T platform as an IP backbone for interconnection of LANs

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Abstract: DVB-T technology has traditionally been used as an access network, providing digital TV programs along with IP based multimedia services to single end users. This paper presents an additional usage of DVB-T as a backbone for the interconnection of Local Area Networks, scattered all over the DVB-T coverage area.

Key Words: DVB-T, WLAN, LAN interconnection.

1. Introduction

The evolution of Digital Video Broadcasting (DVB) and its exploitation over terrestrial broadcasting environments (DVB-T) is one of the most revealing technological developments in wireless telecommunications. Until recently, DVB-T was used mainly as a medium for broadcasting "bouquets" of digital TV programmes to a large number of viewers scattered over large geographical areas (i.e. metropolitan territories) [1]. The intrinsic, however, characteristic of DVB-T to combine heterogeneous traffic (e.g. MPEG-2 TV programmes and IP services) into a single transport stream, enabled for the usage of DVB-T as the "last mile" technology in networking infrastructures for the provision of IP based services. Recent terrestrial networking implementations utilise DVB-T as a downlink channel for the provision of IP services to single end-users, i.e. users that are equipped with a DVB-T compliant receiver modules. The uplink channel is usually based on common PSTN/ISDN telephone lines.

However, in cases where a substantial number of end users is located within a small area (i.e. forming a LAN), the DVB-T technology may be used as a backbone for the interconnection of these LANs, which can be many kilometres away. These LANs can be wired (within the building of a company or a flat of apartments), or wireless, where the PCs are located in relatively short distances (e.g. 100 m) from a central node. This node is actually the LAN's gateway. In such a case, the DVB-T stream can be used as the downlink channel of a wireless backbone that is able to interconnect a number of LANs, while the uplink may be based on another broadband wireless technology, such as the Wireless Local Area Network (WLAN) technology.

This paper proposes a cellular network architecture that is able to interconnect a number of LANs scattered over a large geographical area. A DVB-T platform offers the downlink connection between the Service Provider (SP) and the gateway of each LAN. The uplink channel, (from the gateway to the SP) is a broadband wireless point to point link based on Direct Sequence Spread Spectrum technology. The paper presents the implementation and performance evaluation measurements of a prototype IP based network that utilises the above architecture[1]. The network that is implemented ranges between a SP and two LANs, each located at a distance of about 5 km away from the SP. For the DVB-T downlink the channel 36 in the UHF frequency band was used. In the configuration tested and evaluated, the end-users of the LAN were connected to their corresponding gateway through wireless point to multipoint bi-directional links based on Frequency Hopping Spread Spectrum technology.

[1] This work was undertaken in the context of the Information Society Technologies project MAMBO, "Multi-Services Management Wireless Network with Bandwidth Optimisation", IST-2000-26298.

Following this introductory section, section 2 presents the overall system architecture, section 3 reports on implementation details of a prototype that was served as a test bed for conducting evaluation measurements. Finally, section 4 concludes this paper.

2. Overall system architecture

The overall system architecture, which makes use of the proposed Cellular conception is depicted in figure 1. It consists of a Service Provider that defines a macro-cell coverage area and a number of micro-cells, each defining a LAN. The communication between the LAN's gateway and the service provider is achieved, using a DVB-T stream in the downlink and a point-to-point uplink channel based on Spread Spectrum technology. All IP data from the service provider destined to end users are multiplexed into a single stream (MPEG-2 Transport Stream) and transmitted/broadcasted by the service provider via the DVB-T downlink. Each gateway acts as an intermediate communication node between the service provider and the end-users of the corresponding LAN. It receives the service provider's broadcasts, retrieves the IP data and forwards them to the appropriate end-users that are geographically distributed around the gateway (usually in a shorter distance, compared to that of the service provider). The communication between the gateway and its corresponding end-users is via point-to-multipoint RF links (WLAN) operating in the 2.4GHz band by utilising the IEEE 802.11 protocol. Frequency Hopping technology is used in this link achieving a maximum bit rate of 3Mbps. Each end-user may access the service provider by sending the appropriate data-request to the gateway (through the point-to-multipoint link). The gateway takes the responsibility to deliver these data to the service provider via a point-to-point RF link (uplink) that makes use of the IEEE 802.11b protocol in the 2.4GHz band. Direct Sequence spread spectrum technology used in this link achieves a maximum bit rate of 11 Mbps.

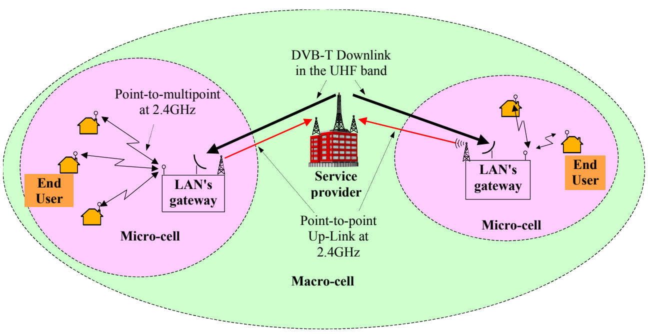

Fig. 1 Overall system architecture

2.1 Service provider configuration

The service provider, the configuration of which is depicted in figure 2, receives the end-users' requests (forwarded by the corresponding gateway), processes them and sends back the appropriate replies. At the service provider's receiving end, a number of receiver devices forward the end-user's request via a HUB to an IP routing gateway. This machine is equipped with two Ethernet adapters" and runs under the MS Windows 2000 operating system. The end user's requests are captured by "Ethernet adapter 1" and passed to the service provider's local Ethernet via the "Ethernet adapter 2". This IP forwarding is achieved by utilising IP filtering software that allows the data flow in one direction only, i.e. from "Ethernet adapter 1" to "Ethernet adapter 2" (data traffic from the LANs to the service provider). In this way, the IP routing gateway blocks the reply data to be forwarded back to the point-to-point RF link. Such an IP routing gateway was implemented for the needs of the paper.
A request for multimedia services is then delivered (by the local Ethernet) to the multimedia server and processed there; the corresponding reply is forwarded back to the local Ethernet, from where it is passed to the "IP/DVB converter". This module, encapsulates the IP packets into a single MPEG-2 Transport Stream that carries all IP traffic, intended to all LANs. The output of this converter, which is an MPEG-2 Transport Stream in Asynchronous Serial Interface (ASI) format, is then Coded Orthogonal Frequency Division Multiplex (COFDM) modulated and up-converted to a suitable frequency within the UHF band (DVB-T transmission chain). The produced RF signal, is passed to a power amplifier and broadcasted to all LANs. It should be noted that this signal might also carry the data of a few digital MPEG-2 TV programmes (according to the DVB-T standard).

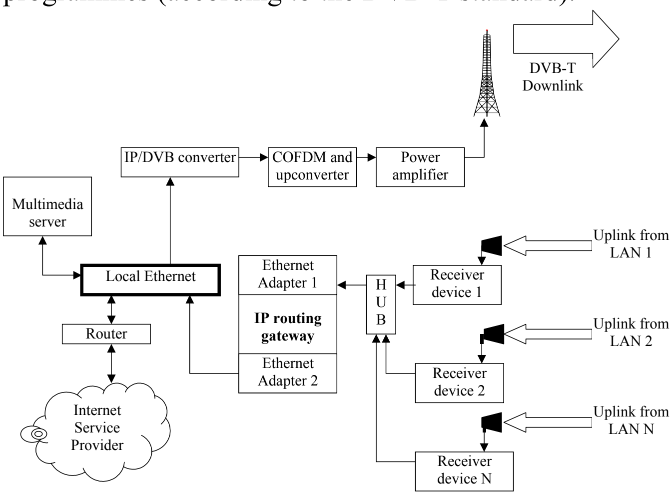

Fig. 2 Service provider configuration

A request for Internet provision is forwarded by the local Ethernet to a router and then to the appropriate Internet Service Provider (ISP). The latter takes over the responsibility of processing the end-user's request and produces the suitable reply. This reply is delivered back to the router, which passes it over to the DVB-T transmission chain. Finally, the reply data are broadcasted to all gateways at the micro-cells.

2.2 Configuration of the micro-cell

The configuration of a micro-cell is depicted in figure 3. Each gateway acts as an intermediate module between the service provider and the end-users of the corresponding micro-cell. It delivers the users' requests to the service provider, receives from the service provider the responses, and distributes them back to the end-users. Such a device was implemented for the needs of this paper. It is a PC based machine equipped with a DVB-T compliant reception card and two Ethernet cards, appropriately configured. The DVB-T reception card receives the service provider's broadcasts, demodulates it and produces the appropriate IP data onto the dedicated PC's internal bus. This dedicated PC, which is running under the MS Windows 2000 operating system, filters the IP packets, by examining their destination address, and forwards them to the cell's LAN via an "Ethernet adapter A".
The local Ethernet delivers the reply signal to the appropriate wireless user through a Wireless LAN transmission/reception device. The user receives the service provider's response (to his/her request) and can subsequently issue another. In the other direction, the cell's local Ethernet receives the wireless user's request, which passes it to the "Ethernet adapter A". The latter forwards it to the return path transmission device via an "Ethernet adapter B". This is achieved by utilising similar IP filtering software as the one use in the service provider. Finally, the request is passed to the service provider via a point-to-point uplink.

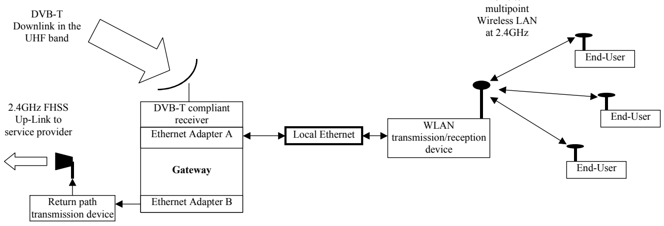

Fig. 3 Cell configuration

3. Performance evaluation

A prototype network following the system architecture described in the previous sections has been implemented in the context of the MAMBO/IST-2000-26298 project, for validating the design and the performance of such a networking infrastructure.
This section reports on the results obtained in a real condition outdoor environment. The experimental platform consists of one service provider, located at the premises of N.C.S.R "Demokritos," and two cells; Cell-1 was approximately 5 km away from the service provider. The gateway of this cell was placed within the Cultural Center of Psychiko municipality, in the area of Athens. Cell-2 was approximately 4km away from the service provider and 3km from Cell-1. The corresponding gateway, was placed within the Town hall of Philothei municipality. Each cell defines a small coverage area of radius approximately equal to 0.2km (operating range of the WLAN). Thus the two cells cannot communicate to each other directly. Each cell defines a LAN, namely LAN-1 and LAN-2 correspondingly. The communication in both cells between the gateway and the corresponding end users is achieved through FHSS point-to-multipoint links. The system operates in half duplex mode and allows an actual total bit rate up to 1.8 Mbps. In case of many users access, the total bit rate is fairly shared among all LAN users [2]-[3]. For the prototype the downlink DVB-T channel (between the SP and the gateways) operated in 594MHz (channel 36). FFT size of 8K, 16 Quadrature Amplitude Modulation (QAM) scheme, Guard Interval of 1/4, and Code Rate of 1/2 were also used, resulting in a total bandwidth of 9.5Mbps. Out of this total bandwidth 2Mbps were allocated for IP services and 7.5Mbps for television programmes distribution.
The implemented network was used to demonstrate the proposed network architecture and also served a test-bed to measure the performance of the network, during the provision of multimedia services. In these tests two wireless end-users were realised, User A in LAN1 and User B in LAN2. During these tests, both wireless users were requesting the download of a 50MB file, hosted by the multimedia server in the service provider site, by utilising the File Transfer Protocol. The results of this experiment concerning the bit rate provided to each cell and also the sharing of the total bit rate between the cells, are shown in figure 4. The upper graph of this figure shows the downloading bit-rate achieved by user B versus time. The middle graph shows the bit rate achieved by user A, while the lower graph shows the total bit rate provided by the service provider.
Initially, User A started the download of the 50MB file, while user B was inactive, and the achieved downloading bit rate was at 1.8Mbps (maximum rate of the WLAN). In this case the total bit rate provided by the service provider was also 1.8Mbps. When user

B became active (both users were downloading the 50MB file), each user was accommodating a bit rate of 1Mbps, while the total bi rate provided by the SP was 2Mbps. After the download completion of user A, the bit rate that user B luxuriated was raised to 1.8Mbps, and the total bit rate provided by the SP was reduced to 1.8Mbps. From these results it can be verified that the described network fairly shares the available network resources between the two LANs.

In the proposed network configuration and the described prototype test bed, the end users are wirelessly connected to the gateway of their corresponding micro-cell. Alternatively, end users may be connected through a wired infrastructure (i.e. Ethernet 10Base-T). Such an implementation is advisable in cases where all end users of the LAN are located within a building, i.e. a block of apartments or a company. The gateway of such a LAN may be placed at the rooftop of the building and each inhabitant/employee is directly connected to the gateway through a UTP cabled infrastructure.

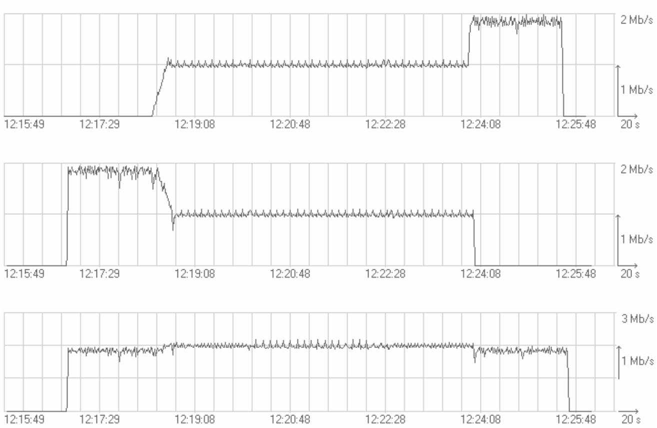

Fig. 4 Bit rate at each LAN vs time.

4. Conclusions

This paper illustrated the use of a DVB-T platform as an IP backbone for interconnection of LANs. It described the overall network configuration according to which a prototype IP based test-bed was implemented, ranging between a service provider and two wireless LANs. The communication between the service provider and the gateway of each LAN is achieved via the DVB-T stream in the downlink, while the up-link traffic is via individual point-to-point Spread Spectrum links. End-users, access the service provider via their LAN's gateway through wireless point-to-multipoint Spread Spectrum links. Performance evaluation tests, conducted on the prototype, verified the validity of the proposed design and the fair sharing of the available bandwidth resources among all LANs.

References:

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