Mobility Issues in a DVB-T Environment

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Abstract: - Digital Video Broadcasting (DVB) is the leading technology for permitting digital television access to a wide repartition of users. There exist many different types of DVB technologies: DVB-T for Terrestrial, DVB-S for Satellite, DVB-C for Cable, each one with its own specifications. This paper focuses on the DVB-T mechanism and the way it handles mobility; it describes all the mobility issues and challenges arising from this technology. Investigations on the integration of the Internet Protocol, IP, over the coming terrestrial digital television standard, DVB-T, are also included. It presents mobility scenarios in a special DVB-T environment, along with a complete broadcasting architecture, in which all leading mobile technologies coexist, and provides solutions and enhancements for a better technology deployment.

Key-Words: - DVB-T, Mobility, Internet Protocol, Digital TV

1 Introduction

Concerning broadcasting standards, Digital Video Broadcasting (DVB) [1] is expected to be the prominent television broadcast standard for next decades, as well through a satellite-based technology (DVB-S), as in terrestrial television (DVB-T), or cable (DVB-C). The evolution in satellite digital broadcast has lead to wide variety of Internet and multimedia applications, even in the few first years of service launch. Even though being member of the same protocol family, terrestrial digital television standard (DVB-T) [2] sets quite different constraints on performance than satellite digital television (DVB-S).

Furthermore, the growth in wireless networks predicts an increasing role of wireless communication techniques in the future and consequently, mobility is taking an important role in next generation services. DVB-T provides a relatively high bandwidth data channel but it is only unidirectional. Mobile multimedia terminals require also a return channel through different techniques, such as WLAN or UMTS. Thanks to DVB-T technology, a wide area of potential users can be covered, called the Broadcasting Area. Switching from one Broadcasting Area to another or within the same Broadcasting Area, from a frequency to another, represents the principal challenge to overcome for achieving personal mobility.

Interoperation of digital video broadcasting standards and Internet protocols based services represents one main evolution in next generation of new services for digital television. Permitting this integration seems essential for the deployment of future network technologies. Furthermore, evolution on portability and mobility has also effects on use and performance of Internet protocols, investigations must be held at the layer-3 level. And this has to be considered when dealing with combination of the two DVB-T and IP protocols.

In this article, we present the mobility issues arising from the terrestrial television broadcasting standard, DVB-T. A complete architecture is presented, for which any mobility scenario is depicted, based on layer transition, from one designed technology to another, featuring WLAN and UMTS and the integration of IP technology. New mobile solutions are developed on novel mechanisms from one broadcasting area to another and enhancements are suggested in order to optimize such mechanisms. Also, the European project ATHENA through which the validation and integration of this approach will be achieved is outlined.

2 Context and Motivations

2.1 Importance of Mobility in DVB-T

Mobility support in DVB-T represents an important parameter for the deployment of this technology. In countries, where a wide wired backbone has already been set up, there is not really a will to promote DVB-T. Besides, xDSL technologies represent a very competitive solution for two main reasons:

- First, since not much infrastructure needs to be added;
- Second, because xDSL permits the end-user to receive TV programs as well as Internet access, thanks to its high bit rates.

As a consequence, in that case, DVB-T is facing some high difficulties to be deployed. On the contrary, if the support of mobility by DVB-T is achieved, then this technology will have an important added value compared to xDSL. With the combination between mobile technologies such as WLAN and UMTS, people will be able to receive their broadcasted favorite programs or an Internet access wherever they are (inside a Broadcasting Area settled by a DVB-T transmitter) and no matter how they move. Furthermore, this represents a feature that cannot be addressed by the xDSL technologies.

2.2 Broadcast Mobile Convergence

DVB-T, although primarily developed for fixed reception with roof-top directive antenna and portable reception, may also be used for mobile TV services. Investigations and trials [3] on this domain have already confirmed the feasibility of mobile DVB-T services provided a robust modulation scheme as well as a suitable receiving system, are adopted.

Studies have been elaborated for using DVB-T standard to deliver broadcast services to mobile receivers. They have shown that the 8k mode is only viable with slowly moving terminals. For the others, a 2k mode is required. Referenced studies indicate that a 2k mode using 16-QAM and a code rate of ½ or 2/3 provide sufficient error performance up to high speeds. It has to be noted that both studies were looking at mobile reception of MPEG-2 coded video streams (TV programming). This type of transmission imposes very strict quality requirements: since transmission is real-time, errors, which are not recoverable by channel coding, cannot be corrected through retransmission.

In a context where the radio spectrum is extremely busy and where the availability of a UHF channel is so complicated and expensive, transmitting only few programs, even if receivable in mobile reception is definitely not acceptable for broadcasters. To overcome this problem, taking into account that for mobile reception, small LCDs are usually adopted (for example mounted in the cars head-rests), the encoding process can be done at low bit-rate (i.e. less than 500 kbps, in CIF format 352x288), followed by MPE encapsulation and transmitted on a DVB-T channel. Hence, there exists the possibility of using DVB-T for the delivery of IP-based multimedia services to mobile terminals. Such experiments have been held [3] and proved the feasibility and efficiency of this solution, using IP over DVB-T mechanism [3].

3 Overall Configuration of the DVB-T Environment

The environment herein consists of an infrastructure which uses regenerative DVB-T streams for the interconnection of distribution nodes, enabling access to IP services and digital TV programs in wide areas such as big cities. Such a configuration enables multi-service capability, as regenerative DVB-T creates a single access network physical infrastructure, shared by multiple services (i.e. TV programs, interactive multimedia services, Internet applications, etc...). In this approach, the DVB-T stream is used in a backbone topology and thus creates a flexible and powerful IP broadband infrastructure, thus permitting broadband access and interconnection of all local networks. Figure 1 shows an overall representation of such an environment. The Broadcasting Area is provided with regenerative DVB-T streams by the Central Broadcasting Point (CBP). Cell Main Nodes (CMNs) enable a number of simple users (geographically neighboring the CMNs) to access IP services hosted by the network. Each CMN constitutes the 'physical interface' to the common Ethernet backbone of users/citizens of a local network (i.e. IEEE 802.11x), customers of a mobile network operator making use of 3G and B3G technology (i.e. UMTS), individual users and service providers. In such configuration, both reverse and forward IP data traffic are encapsulated into the common DVB-T stream, thus improving the flexibility and performance of the network.

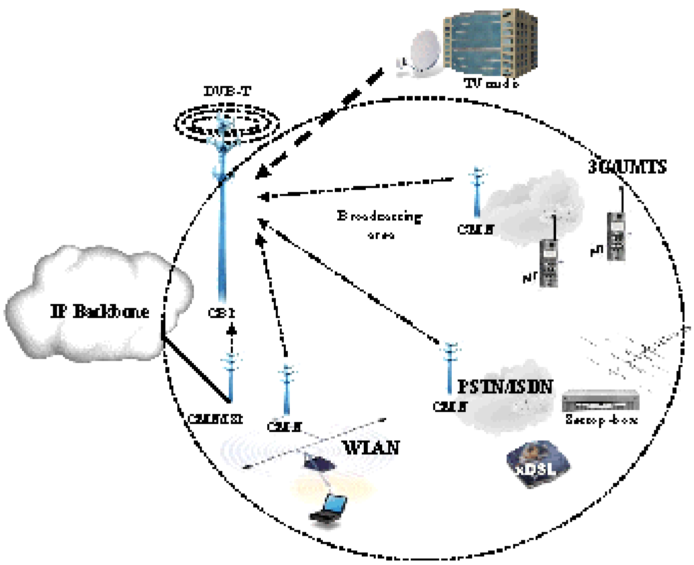

Figure 1: Overall Network Configuration

The IP data stemming from the CMNs, consisting of either requests/acknowledgements or of useful data, are forwarded to the CBP to be included in the common broadcast downlink. This traffic will be conveyed via unidirectional point-to-point wireless links, acting as return channel trunks. The technology adopted for the implementation of the return channel can be any point-to-point wireless data transmission technique, without need for additional link-level procedures, like multiple access schemes or error resilience via retransmissions.

4 Mobility in DVB-T Environment

The overall configuration of the DVB-T environment has been depicted above, along with the requirements on such an infrastructure. The intention now is to provide mobility in such an environment. An example could be a mobile user equipped with a DVB-T receiver willing to access services inside a train traveling from one city to another, the cities being covered by two or more broadcasting areas. In that case, the mobile user will switch from one broadcasting area to another and handovers will occur.

We first state the mobility problem and then we focus on the DVB-T mobility process, the most critical one. However, since the intention is to deploy a fully mobile DVB-T access network, all the eventual features are being outlined, from layers of mobility to specific handovers.

4.1 Mobility Problems Statement

In this study, we try to incorporate the widest range of scenarios on mobile terminals in a DVB-T environment. There exist different types of mobile terminals; we will distinguish them through their reception technology:

- Terminals with a DVB-T reception antenna, which can be divided in:
    - Terminals that can receive the MPEG-2 programs directly, thanks to their DVB-T reception device, such as set-top boxes;
    - Terminals that can receive IP audio/video streams, such as personal computers equipped with a DVB-T board;
- Terminals with a UMTS interface, such as mobile phones;
- Terminals with a WLAN interface, such as laptops and PDAs.

Of course, a mobile terminal can as well be equipped with several reception devices, e. g. a UMTS and a WLAN (IEEE 802.11x) interface or other combinations. A complete mobile terminal could be a car equipped with a DVB-T antenna and a UMTS interface, in which several laptops or PDAs are linked through a WLAN network.

The mobility aspects underneath represent the interesting points in this work. Mechanisms are studied for seamless reception of digital TV and IP data, when transition from one UHF channel (DVB-T stream) to another is required, or when terminals move from one point to another, experiencing handovers. Those handovers may occur at different levels, the most common one being between CMNs.

4.2 Mobility Treatment

In this particular environment, we can distinguish several mobility issues, either on the concern of access networks behind CMNs (WLAN and UMTS devices), or switching between CMNs and experiencing layer-3 handovers and finally, at a larger scale between broadcasting areas.

Concerning access networks behind CMNs, such as WLAN and UMTS, solutions for achieving mobility in those cases are known and exploited. The first challenge, now, is to support the mobility case when a mobile user equipped with a DVB-T receptive device switches from one broadcasting area to another or inside the same broadcasting area from a frequency to another. A second objective is to permit the accessibility of IP services by no DVB-T receivers, located behind CMNs and able to perform mobility actions from one CMN to another. For this point, we propose an extension of Mobile-IP efficient layer-3 handover solution.

4.2.1 From one Broadcasting Area to another: DVB-T mobility

A DVB-T receiver moving from one DVB-T area to another has to keep the service continuity. In a MFN (Multi Frequency Network), the DVB-T receiver has to tune a new frequency and, eventually, to get the new transport stream providing the same service when it performs a handover. This represents DVB-T mobility.

The issue of DVB-T mobility has to be taken into account, especially when the mobile user is moving from one Broadcasting Area to another (both utilising the same infrastructure), or when switching from one UHF channel to another (within the same area) due to traffic loaded DVB-T streams. This scenario is depicted Figure 2. In this respect, a traffic policy mechanism is required, which, in collaboration with the bandwidth management system, will route/direct the data traffic destined to a specific citizen, via the appropriate DVB-T stream (proper UHF channel within the same area or among different territories), in order to provide seamless access to the targeted services, besides enabling for any-time, any-where ubiquitous services distribution.

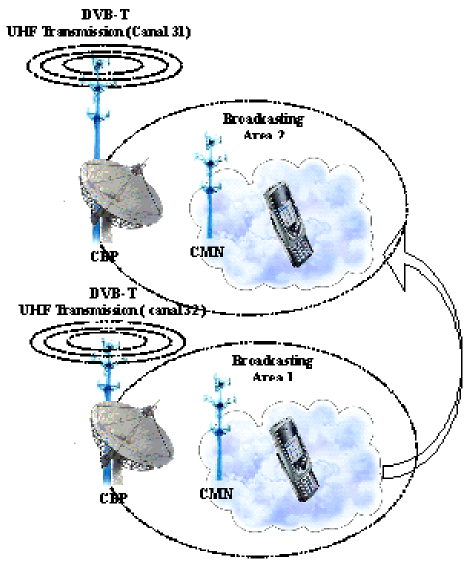

Figure 2: DVB-T Mobility Scenario

The handover issue is depicted in Figure 2, where a mobile user, initially located in city 2, is accessing IP multimedia services via its UMTS device, while the appropriate reply signals are forwarded to him via the regenerative DVB-T stream. As this user moves towards a new BA, he leaves behind the first broadcasting area, and enters the broadcasting area of city 1.

For seamless reception and uninterrupted access to the provided services i) the user must switch his DVB-T receiver device to the new UHF channel, and ii) the core infrastructure must redirect the IP traffic (targeted to him) from regenerative DVB-T 2 to the regenerative DVB-T 1 platform (located in city 1). In this respect, a handover policy mechanism is required for enabling efficient redirection of the IP traffic and fast transition from one UHF channel to another.

Towards this, we propose the following mechanism: a Location Aided DVB-T Handover (LADH) policy mechanism, capable of providing DVB-T mobility and able to interconnect cities that make use of regenerative DVB-T platforms. This mechanism will monitor the geographical position of the mobile user, i.e. by making use of the location and direction data that will be available at the user's Mobile Terminal Device. The Location and Direction Information (LCDI) data will be provided via the UMTS uplink to the LADH module, where it will be processed and compared with Coverage Information (CI) and Road Topology (RT) data, related to the coverage area of each regenerative DVB-T platform stored in an appropriate GIS database. The LADH module will decide if traffic redirection is required or not. In case that traffic redirection is essential, i.e. mobile user is leaving city 2 and enters city 1, the LADH module will signal the Traffic Policy Mechanism (TPM) that the mobile user needs to switch to the new UHF channel. The TPM will accomplish this by providing the mobile user with the appropriate control data encapsulated in the DVB-T stream of the appropriate channel. At the same time, the TPM will reroute all IP traffic targeted to this user, from regenerative DVB-T 2 to regenerative DVB-T 1. As a result, the mobile user's receiver/demodulator will switch to the new UHF channel (upon reception of control data), and the regenerative DVB-T 1 will broadcast the IP services (targeted to this user) via its regenerative DVB-T stream.

This mechanism based on a LADH and with the use of a TPM represents the solution for achieving DVB-T mobility in the presented architecture, when a mobile terminal switches from one BA to another or from a UHF frequency to another within the BA and is depicted Figure 3.

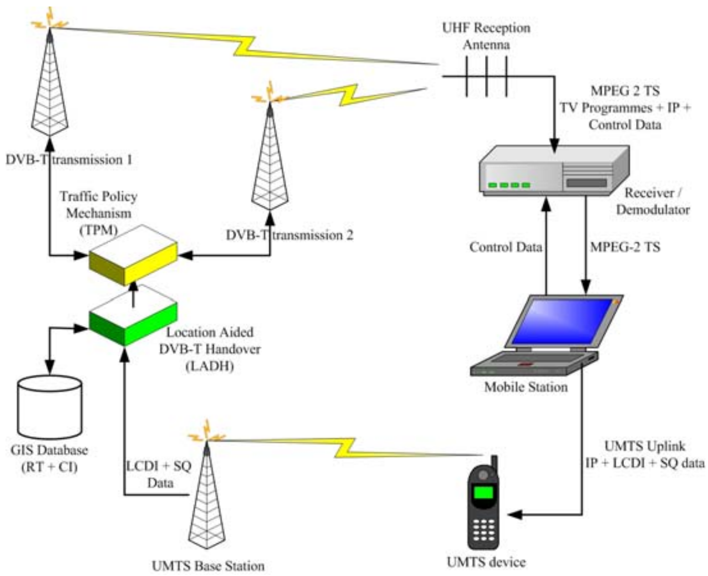

Figure 3: LADH Policy Implementation

4.2.2 Mobile IP Extension for Layer-3 Handovers

Layer-3 handovers, with IP address switching, occur in two special cases:

- When a mobile terminal connected via a IEEE 802.11x interface to an access point in a WLAN switches from one CMN to another; it then performs a horizontal handover between CMNs with WLAN technology. This scenario is depicted Figure 4;

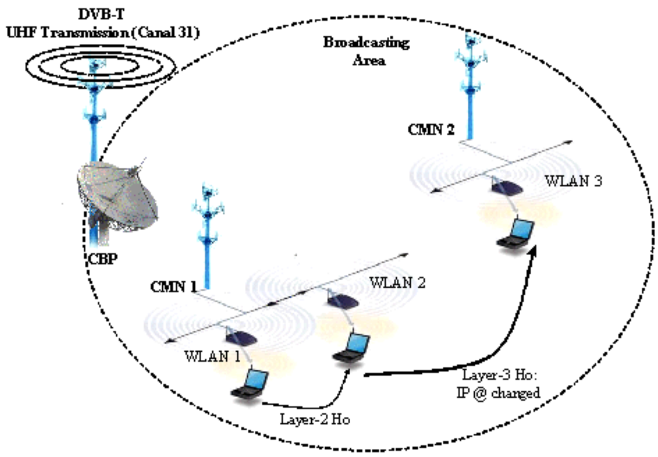

Figure 4: Layers Handovers Mobility Scenarios through WLAN Technology

- When a mobile terminal connected via a IEEE 802.11x interface to an access point in a WLAN switches to its UMTS interface in a cellular area (and vice versa) either inside the same CMN or between two CMNs; it then performs a vertical handover from WLAN to UMTS or vice versa. A representation of this scenario can be seen Figure 5;

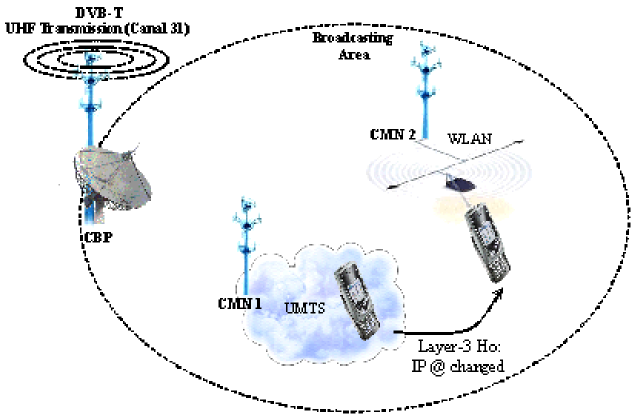

Figure 5: Vertical Handover UMTS/WLAN Mobility Scenario

The proposal for these kinds of scenarios is based on Mobile IP. Mobile IP facilitates node movement. It allows a mobile node to communicate with other nodes (stationary or mobile) after changing its link-layer point of attachment from one IP subnet to another, yet without changing the mobile node's IP address. A mobile node is always addressable by its home address, and packets may be routed to it, using this address regardless of the mobile node's current point of attachment to the Internet. Mobile IP adds a novel address, known as the mobile node's care-of address, which has the same network address as the visited foreign subnet. The mobile node will configure its care-of address by stateless address auto-configuration. The association between a mobile node's home address and its care-of address is called binding. Each IP node maintains a Binding Cache, where it stores the currently valid bindings.

Herein, we have a broadcasting architecture; therefore all the CMNs receive all the flows (TV+IP) transmitted by the CBP. After the de-multiplexing and de-capsulation process of the IP over DVB-T streams, as described above (section 0), the routing module of each CMN decides either to redirect the packets to the terminals behind it or to destroy them according to their IP addresses. It's a common routing process. Every CMN receives all the IP packets and destroys those that don't belong to the adjacent subnets.

We propose the following MIP-based mechanism for supporting layer-3 handovers in this architecture. First, the mobile terminal (or Mobile Node, in MIP terminology) has a home address and receives a care-of-address, when accessing a new subnet, covered by a new CMN. At that point, the Mobile Node will inform the designed router of the CMN that it has joined its subnet and that a binding must be established between its home address and its care-of-address. A binding update message will be sent to the Designed Router (DR) and the DR will reply with a binding acknowledgement, the same it is done in MIP. The DR is considered as a pseudo Home Agent. Since it receives all the IP traffic, it could establish a binding cache and retransmit the packets destined to an entry in the binding cache to the respective care-of-address, instead of dropping them. Timers should be set and signalling messages between the DR and the mobile terminals that correspond to an entry in the binding cache need to be addressed. For example, every 2 seconds, a discovery message from the DR is sent to the care-of-addresses of the MNs present in the binding cache. If there is no response from the MNs, it means that the MN is not in the subnet anymore and consequently, the corresponding entry in the BC is deleted.

This mechanism permits to provide seamless mobility when layer-3 handovers are performed. It is based on Mobile IP principles and lightens the signalling part.

5 IST Project: ATHENA

The EU-funded IST Project ATHENA (ATHENA - Digital Switchover: Developing Infrastructures for Broadband Access [5]), which started in January 2004, takes into consideration the mobility concepts defined in this paper, as well as the overall network configuration. ATHENA proposes the use of the DVB-T in regenerative configurations and exploits the networking capabilities of the television stream for the creation of a powerful backbone that interconnects distribution nodes within a city. As these distribution nodes (local networks) make use of broadband access technologies (i.e. the 'local loop', WLAN, LMDS, MMDS, Optical) they enable all citizens to have broadband access to the entire network and to be interconnected. Such a configuration enables for multi-service capability, as the regenerative DVB-T creates a single access network physical infrastructure, shared by multiple services (i.e. TV programs, interactive multimedia services, Internet applications, etc.). In such approach, the DVB stream is used in a backbone topology and thus creates a flexible and powerful IP broadband infrastructure.

Among its objectives, the ATHENA European project is conducting research activities in DVB-T system and mobility. One of the goals of this research project is to set the proposed architecture described in this paper and make feasible such scenarios of mobility, with the proper solutions and enhancements presented thereby. Therefore, the ATHENA project consists of a perfect support for integrating and developing at a large scale, mobility aspects, issues and proposed solutions.

6 Conclusions

In this article, we propose an architecture that takes into consideration the use of regenerative DVB-T streams for the transport of both TV programs and IP flows at the same time and through the same frequency channel. It is based on a Central Broadcasting Point (CBP), which transmits and regenerates the streams and Cell Main Nodes (CMN), which group different wireless and fixed access networks to permit users to be interconnected and to receive services.

In order to make such a proposal feasible and since wireless access networks are primordial nowadays, an important and most innovative issue is to handle mobility. The paper focuses on this part. It presents all the possible mobility scenarios in such a DVB-T environment, covering all the wireless access networks from WLAN to UMTS and depicting all the types of handovers, layer-dependent, technology-dependent, and taking into consideration the integration of IP. We propose solutions and enhancements for achieving seamless mobility in each case. First, a Location Aided DVB-T Handover (LADH), along with a Traffic Policy Mechanism (TPM), is proposed for DVB-T mobility issues. Also, when layer-3 handovers occur, an efficient Mobile IP based mechanism is presented and designed to undertake proper actions.

The aim of an architecture of that nature, which includes such mobility solutions, is to be easily set up and deployed, in all contexts. That is one of the main objectives of the ATHENA European Project.

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