Transition from analogue to digital broadcasting in UHF: The ATHENA Concept

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Abstract: In Sevilla European Council (21-22 June 2002), the European Commission recognised the importance of broadband access infrastructures for the successful deployment of Information Society (IS) throughout the Union by 2005, and identified the actions to be taken, among which is the transition from analogue to digital broadcasting (DSO). In a number of EU states where broadband networking infrastructures have already been disposed, DSO in UHF does not constitute a critical issue for the successful deployment of IS. In all other EU countries, however, where the low penetration of broadband access infrastructures hampers the successful deployment of IS, digital switchover arises as a unique opportunity to fill the gap and shorten the digital divide. In this respect, this paper presents an approach – that has been adopted and elaborated with the ATHENA FP6-507312 project – for the proper adoption of DSO that provides the basis for fast and successful establishment of broadband infrastructures, especially in the less developed regions. Taking into account the local and networking aspect (IP capabilities) of the new digital terrestrial television (Terrestrial Digital Video Broadcasting – DVB-T), it describes a Fusion environment that enables broadband access not only to digital TV bouquets, but also to Information Society services, besides being offered to all existing and potential service/content providers for open competition at all levels (technological, service, content creation and distribution).

Key-Words: Digital Switchover, Broadband access, Fusion environment, regenerative DVB-T

1 Introduction

In Sevilla European Council [1], Europe defined the actions-to-be-taken and identified the issues to be studied prior to the establishment and the successful deployment of Information Society (IS). Among them, the issue of "Convergence" between broadcasting and telecommunication sectors arises as a key element with main implications over the technological, social, cultural and economic growth of European citizens/regions.

Despite, the intrinsic technological differences between Telecommunications and Digital Broadcasting sectors, a notion of convergence has been recently achieved not only at technological level, but also at service level. This convergence was mainly empowered in European level by the work carried out in the field of 'Interactive Broadcasting', which was the subject of innovative work carried out by a number of Research and Development projects in the 5th European Framework Programme. The objective of further development of the subject of Interactive Broadcasting (as a key element towards the successful deployment of IS) was confronted by the European Commission in a lately organised workshop that identified the technological and service issues that require further R&D effort, which include – among the others – i) **regulatory and spectrum issues**, and ii) **the need for synergy** (better than convergence) **between broadcasters and telecom operators towards the realisation of common exploited and compatible platforms.**

In this context, a number of actions have been carried out the last years by the Commission, including EC funded projects, public consultation meetings, public hearings, communications, vision documents, studies and reports for both the synergy between the broadcasting and telecommunication sectors([2], [3], [4]), and the regulatory/spectrum issues ([5], [6]).

Following these actions and based on the Commission's guidelines (expressed in [1]), this paper anticipates that both the regulatory/spectrum issues and the synergy between broadcasters and telecom operators can be efficiently confronted by the proper adoption of the Digital Switchover, i.e. the proper transition from analogue to digital terrestrial broadcasting.

In this context, this paper proposes a DSO approach that i) delves into the spectrum issues (currently examined by the Commission's Radio Spectrum Policy Unit) and ii) enhances the synergy between broadcasting and telecommunication sectors towards a more dynamic stage: the realisation of a Fusion environment which does not belong to any broadcaster or 3G operator, but it is used/exploited as common infrastructure by i) 3G, and B3G operators and broadcasters having independent business plans and different users/clients, and ii) by any spin-off businessman in the field of broadcasting/multicasting/networking.

It presents the architecture of such a Fusion environment (i.e. a TV UHF channel that has been set-up and running in Heraklion city 24-hour-a-day since 1st of August 2004, serving as the ATHENA FP6-507312 IST project demonstrator), which realises the capabilities and potentialities of the deployed Digital Switchover (DSO), which enable for:

1. the provision of a variety of heterogeneous bit rate services, like MPEG-2 TV, IP TV bouquets, Internet access, e-mail access, multimedia services on demand and/or in multicast form,
2. the creation of a single access broadband physical infrastructure with multi-service capabilities, able to interconnect IP nodes at Heraklion (and/or individual users), besides accommodating broadcast services (digital TV programmes),
3. the deployment of an infrastructure that is commonly exploited among 3G and B3G operators and Broadcasters having independent business plans and different user/clients,
4. the introduction and presentation of the notion of the active user (the MPEG-21 user), accommodated by an 'access network' that enables him to receive and distribute services/applications to the entire city of Heraklion,
5. the realisation of each active user as a potential service/content provider (spin off activities, e-business),
6. offering the possibility to realise (at any Heraklion neighbourhood) broadband access hot spots (i.e. WLAN based CMNs), the content of which is supplied via the television beam,
7. the provision of broadband services and also Internet, e-mail even to passive citizens connected to the entire infrastructure via PSTN based CMN.

Following this introductory section the rest of this paper is structured as follows: Section 2 presents the overall architecture according to which an infrastructure has been implemented, set-up and is running in Heraklion city. Sections 3 to 9 describe how such an infrastructure realises the pre-mentioned potentialities and capabilities of DSO towards a Fusion environment, while Section 10 concludes the paper.

2 Overall Architecture

The overall architecture of such a fusion environment is depicted in Figure 1. It describes a DVB-T channel that utilises the regenerative conception that comprises two core subsystems: I) a number of Cell Main Nodes (CMN), and II) a central broadcasting point (regenerative DVB-T). Each CMN enables a number of users/citizens (geographically neighbouring the CMN) to access IP services hosted by the network. The communication between the users and the corresponding CMN is achieved via broadband point-to-multipoint links (i.e. WLAN). The CMN gathers all IP traffic stemming from its users, and forwards it to the central broadcasting point (UHF transmission point visible by all CMNs) via dedicated point-to-point links (uplinks). IP traffic stemming from all CMNs is received by the broadcasting point, where a process unit filters, regenerates and multiplexes them into a single transport stream (IP-multiplex) along with digital TV programme(s), stemming from the TV broadcaster(s), forming the final DVB-T "bouquet". The regenerated/combined traffic is then broadcasted via the UHF channel at high data rates following the DVB-T standard. Each user receives the appropriate IP reply signals indirectly via the corresponding CMN, while receiving the digital TV programme directly via the UHF channel. 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.

The cellular conception that is adopted utilises DVB-T stream in a backbone topology which interconnects all cells that are located within the broadcasting area. Thus, a unique virtual common Ethernet backbone is created, which is present at every cell (via its Cell Main Node). The IP traffic of this Ethernet is supplied by the DVB-T bit stream. Users access the network via the appropriate Cell Main Node.

In such configuration, all kind of citizens/providers are co-equal users of the same infrastructure via which they access (or provide) IP services. Such implementation can be used and exploited as common infrastructure by 3G and B3G operators and broadcasters having independent business plans and different users/clients.

Extension of this configuration will be achieved by using a regenerative satellite, in order to interconnect nodes and users around Europe.

Citizens, who utilise common PSTN/ISDN/xDSL lines access the common Ethernet backbone via an appropriate node (i.e. ISP node), who takes the responsibility to redirect data traffic targeted to them (IP reply signals stemming from any other user/citizen located within the same broadcasting area) to the UHF broadcasted Ethernet backbone. These citizens are the usual passive consumers of predefined content, accommodating best effort capabilities. This conception is oriented to the active users/citizens that can provide and manipulate their own services to the entire Ethernet backbone (i.e. spin-off businessman, off line IP television multicasters, etc.). The use of regenerative DVB-T configurations in conjunction with intermediate distribution nodes (cell main nodes - CMNs) that utilize broadband uplinks, constitutes a broadband access infrastructure capable to accommodate the active users/citizens, i.e. those who create, manipulate and distribute their own content to the entire network. In this case, each CMN constitutes the ‘physical interface’ to the common Ethernet backbone of:

a) A service/content provider: The users/citizens of a local network (intranet) who access the entire network indirectly via the appropriate CMN. This intranet may cover a part of the city (i.e. neighbourhood, outskirts, industrial zone, etc.) or comprise the LAN of a business centre that may be based on the IEEE 802.11x technology, for example.

b) The customers of a mobile network operator making use of 3G and B3G technology (i.e. UMTS)

In this case a switching/diversion technique is applied: Upon a mobile user’s request for IP services provision, the data stream (data request) is forwarded via the UMTS network to the UMTS multimedia server, which takes the responsibility of producing the appropriate reply data streams. These broadband reply data are forwarded to the regenerative DVB-T via the uplink. Finally, the requested service’s data reach the mobile user via the common DVB-T downlink in the UHF channel (communication path from the regenerative DVB-T to the DVB-T compliant receiver).

c) Individual active users and implicit service providers, who access the common Ethernet backbone via the corresponding CMN in order to create, manipulate and provide their own content to the entire network (i.e. e-businessmen). (Also individual passive users, who request predefined content/services via common PSTN/ISDN/xDSL links and receive them via the UHF beam).

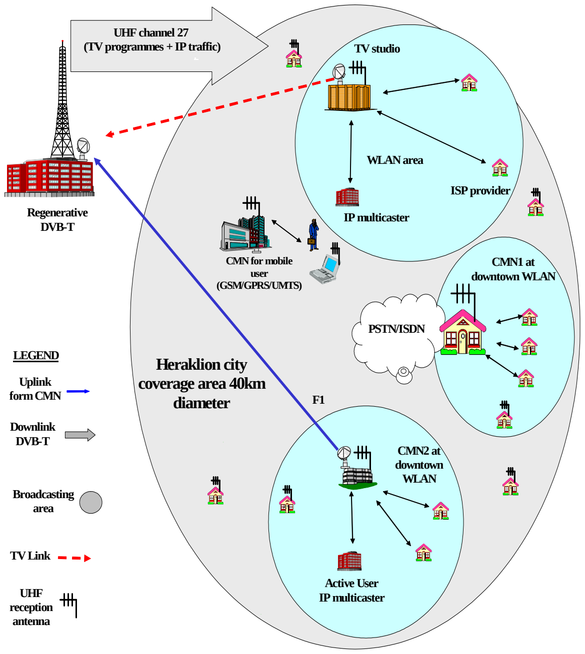

Fig. 1 Overall architecture

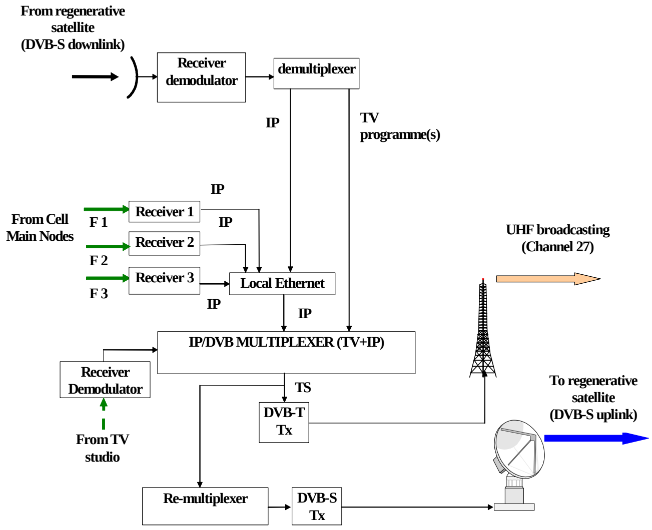

Fig. 2 Regenerative DVB-T configuration

2.1 Configuration of the regenerative DVB-T

The configuration of the regenerative DVB-T (that is depicted in Figure 2) is capable to: i) receive the users/citizens IP traffic over terrestrial uplinks (via the appropriate CMN in the case of intra-metropolitan communication – see F1, F2, and F3 at figure 2), ii) receive any local digital TV programme (stemming from the TV studio broadcasters), iii) broadcast a common UHF downlink that carries the IP data targeting to all CMNs (located within the broadcasting area) and the digital TV programmes.

In this context, and following the configuration depicted in figure 2, the multiplexing device is able to receive any type of data (IP and/or digital TV programmes), to adapt any IP and MPEG-2 traffic into a common DVB-T transport stream (IP to MPEG-2 encapsulation), and finally to broadcast the common DVB-T stream following the DVB-T standard (COFDM scheme in the UHF band).

2.2 Cell Main Node configuration (WLAN case)

The overall configuration of a Cell Main Node (CMN) that utilises WLAN technology is depicted in figure 3. This part of the infrastructure is compliant with the IEEE 802.11x standard. Its physical layer is based on Spread Spectrum techniques, using either Direct Sequence or Frequency Hopping. Such a network will allow for the realisation of point-to-multipoint communication between the CMN and the citizens/users.

The WLAN network configuration follows a cellular architecture, as outlined in figure 3 (for a single cell). Such a configuration comprises an Access Point (AP) at the cell main node site, which maintains a full duplex communication with the Station Adapters (SA) at the citizen's/users' site. The output from each SA is in IP form, which can be transparently processed by the upper layers of the software of the end-user's terminal.

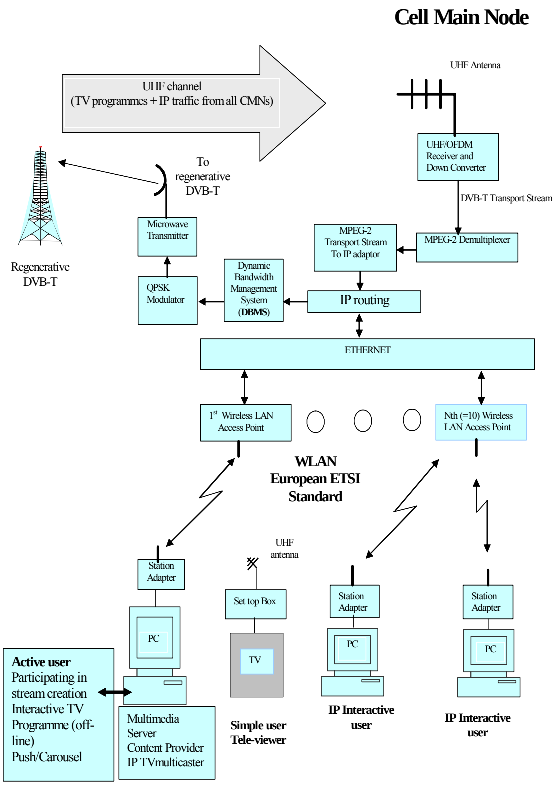

Fig. 3 CMN configuration (WLAN based)

Both reverse and forward IP data traffic are encapsulated into the common DVB-T stream:

The 'Active user' and the 'IP interactive users' generate the IP traffic that is carried via the DVB-T stream to all broadcasting area.

Data IP traffic targeted to these users (and stemming from any other CMN within the broadcasting area) is supplied by the DVB-T stream to the local Ethernet, via the UHF channel.

Summarising, the proposed overall architecture (Figures 1, 2, and 3) realises the DSO by making use of two "pillars":

i) The regenerative DVB-T concept

ii) The "Bit-rate allocation" aspect rather than the "Channel/Frequency allocation" one: the realised common UHF beam of a given bit-rate, shares its bit-rate among all beam participants i.e. broadcasters, telecom operators, active users/citizens, spin-off businessmen, multicasters, ISP providers, etc. Such an approach provides for open and clear competition, in technological and service level, in content creation and delivery level, in networking business/market field. For example, supposing that two users have been allocated the same bit-rate, it is evident that one of them can achieve/create/produce more that the other.

Both these pillars set the basis for the realisation of a Fusion environment that enables for multi-service capabilities, besides virtually contributing to the discussions carrying out by the Commission's Radio Spectrum Policy Unit (RSPU), concerning the Digital Switchover and its implications over the Spectrum Dividend [5].

3 Provision of a variety of heterogeneous bit rate services on demand and/or in multicast form.

Referring to Figure 1, the Heraklion demonstrator comprises a TV studio that creates and distributes his own digital MPEG-2 TV programmes to the entire Heraklion city, similarly to a local broadcaster. These TV programmes are transmitted to the regenerative DVB-T, in order to be multiplexed with the IP-based services, stemming from the active user/citizens (see ISP provider, IP multicaster) located within a WLAN area. The former (ISP provider) enables access to Internet and e-mail services, besides providing for Audio on Demand and Video on Demand applications in the case that a multimedia server is utilised. The latter (IP multicaster) creates, manipulates and distributes his own IP TV programmes, enabling therefore the IP TV bouquet provision. All these services (MPEG-2 TV programmes, Internet and e-mail access, IP TV, VoD, AoD) that are multiplexed at the regenerative DVB-T, form the final DVB-T bouquet to be transmitted to the entire Heraklion city over a UHF channel.

In this respect, the proposed solution for DSO in UHF creates a UHF channel that provides apart from conventional digital TV programmes and a variety of heterogeneous bit-rate services (IP TV bouquets, Internet access, e-mail access, multimedia services on demand and/or in multicast form) to the entire Heraklion city.

4 Creation of a single access broadband physical infrastructure with multi-service capabilities

The adopted DSO approach, revealed and described in Figure 1 for the Heraklion demonstrator, creates a UHF channel that carries and distributes, apart from conventional digital TV programmes and, a variety of heterogeneous bit-rate services (i.e. IP TV bouquets, Internet access, e-mail access, multimedia services on demand and/or in multicast form) to all Heraklion users/citizens. This TV channel constitutes, therefore, a powerful backbone with multi-service capabilities that is present at the entire Heraklion city (40Km diameter). This backbone interconnects all individual CMNs in Heraklion city by providing/feeding them with the appropriate data/services. Users/citizens access these services (and the backbone) either directly via DVB-T compliant equipment or indirectly via the appropriate CMN.

More specifically, each user/citizen receives the digital TV programme(s) (created at the TV studio) directly via the UHF channel, while accessing the appropriate IP data (created by any active user/citizen) indirectly via the corresponding CMN. In such a case (IP services access) the UHF channel constitutes a unique virtual common IP backbone, which is present at every cell (via its Cell Main Node), enabling in this way the interconnection of all Heraklion CMNs. Evidently, users/citizens who access this backbone, can communicate each other via the corresponding CMNs. In this way, the proposed DSO adoption creates a UHF channel that interconnects all CMNs that are located within the broadcasting area, besides enabling for user/citizen interconnection.

Finally, the IP traffic carried by this Ethernet and supplied by the DVB-T bit stream to all CMNs, stems from any user/citizen and targets to any other user located within the Heraklion city. In such configuration both reverse and forward IP data traffic is encapsulated into the common DVB-T stream.

5 Deployment of an infrastructure that is commonly exploited among 3G and B3G operators and Broadcasters having independent business plans and different user/clients

Referring to Figure 1, the Heraklion demonstrator comprises a CMN for serving users/citizens that make use of mobile 3G and B3G technologies (i.e. GSM, GPRS, UMTS). This node (namely "CMN for mobile user"), enables users/citizens to access the Heraklion UHF channel even under portable/mobile reception conditions. Such an architecture/configuration, apart from providing for mobile reception of added value multimedia IP services, it also enables a UMTS operator to be connected to the entire ATHENA infrastructure in order to receive and distribute services (to its customers) that are hosted by the entire network (i.e. created, manipulated and distributed by any current or potential service provider of the ATHENA infrastructure).

Therefore, the proposed DSO adoption, creates a UHF channel that hosts not only digital TV services (stemming from TV broadcasters and targeting to TV viewers) and IP services (stemming from active users/citizens and targeting to IP users), but also enables 3G and B3G operators to participate in the creation of the final DVB-T bouquet, targeting (primarily but not only) to mobile users. In this way, this Heraklion UHF channel becomes a neutral infrastructure commonly shared among all Heraklion citizens (broadcasters, telecom operators, IP multicasters, ISP providers, e-businessmen, etc.), which enables for open, healthy and prosperous competition in both the market and business field.

6 Introduction and presentation of the notion of the active user (the MPEG-21 user), accommodated by an 'access network' that enables him to receive and distribute services/applications to the entire city of Heraklion

Referring to Figure 1, the Heraklion demonstrator comprises a number of users/citizens accessing the

ATHENA infrastructure and the UHF channel via broadband communication links (WLAN based). These users are able not only to intra-communicate (users of the same CMN communicate each other), but also to communicate with others belonging to different CMNs. The existence of the broadband access links enables them to become active users (MPEG-21 approach) capable not only to receive content but also to manipulate and distribute their own data to the entire Heraklion city. In this respect the adopted conception of the Heraklion demonstrator sets-off the potentialities of the DSO to create active users (MPEG-21 approach) accommodated by an access network, which are able not only to receive content (hosted by other Heraklion users/citizens) but also to manipulate and provide their own applications to the entire Heraklion city.

7 Realisation of each active user as a potential service/content provider (spin off activities, e-business)

Considering previous and recent studies/reports it comes that until now both broadcasters and telecom operators consider European citizens as passive consumers/clients of their content/services, and they foresee an increase of such a custom when digital switchover becomes a reality. The passive citizen who receives predefined content/services/applications seems to be the target group of these sectors, which will raise their income and boost their business viability. The active participation, however, of the critical mass of potential content/application providers (stemming from traditional users) in the market is the key to, generate revenue, gear up rich activity in the market chain and spear new progress in the content, the broadcasting and telecommunication sectors, besides attracting new consumers. The critical missing link to enable this active participation of all potential content/application providers, is a broadband access infrastructure, which will decouple the service provisioning function from the network operators and offer this privilege, to all interesting players (active citizens/users) introducing innovative services, generating revenue, competition, quality and market opportunities.

This possibility is offered by the proposed DSO (depicted in Figure 1 for the Heraklion demonstrator) and will be available until the end of ATHENA project (for about 20 months) at Heraklion city.

Adopting the "Bit-rate allocation" aspect rather than the "Channel/Frequency allocation" one, a novel single access infrastructure with multi-service capabilities is created, which provides the conditions for open and clear competition in all fields:

i) Content creation ii) Services distribution iii) Content promotion and maintenance iv) Services manipulation and delivery

The adoption of the new terrestrial digital television, as it is proposed in ATHENA project, "liberates" the intellectual creators (active users/citizens according to the ATHENA terminology), as it allows them to address (accentuate) their work to the entire city, by providing them a part of the bit-rate (some kbps) available in the entire DVB-T beam without obligations, agreements or commitments to any 3G operator or broadcaster (which just co-exist and commonly share the digital bouquet that is available over the whole Heraklion city).

This DSO potentiality constitutes a challenge towards new business plans and market opportunities, either independently of the television/AV and the 3G sectors or exclusively use of the 3G operators. Evidently, the competition must be open, under new ideas and novel approaches, both in the configurations and the new services (new business cases). The existence of such a neutral regenerative infrastructure (DVB-T) in a city, provides not only a bouquet of television programs, but also (and most predominant) creates a powerful broadband IP backbone (the 60 available analogue UHF/VHF channels may be seen as a virtual medium that provides an aggregate bit-rate of about 1.8Gbps).

8 Offering the possibility to realise (at any Heraklion neighbourhood) broadband access hot spots (i.e. WLAN based CMNs), the content of which is supplied via the television beam

Referring to Figure 1, the Heraklion demonstrator comprises two Cell Main Nodes that create broadband access hot spot areas by making use of WLAN technology. Each of these CMNs enables its users/citizens both for intra-communication (users of a specific CMN can communicate each other) and also for inter-communication and access to the entire Heraklion infrastructure (users belonging to different CMNs within the Heraklion city can communicate each other). While the former (intra-communication) is achieved by making use of the principles of WLAN technology, the latter (inter-communication) is provided over the IP backbone created by the Heraklion UHF channel. Content hosted by any active/MPEG-21 ATHENA user, is fed onto the corresponding CMN via the Heraklion UHF channel and forwarded to the appropriate user/citizen over WLAN links.

In other words, these two CMNs, which make use of a widely accepted broadband access networking technology (i.e. IEEE 802.11x), offer the possibility and demonstrate the DSO potentialities to create broadband access hot spots, which serve as intermediate communication nodes enabling access to content that is provided over the UHF channel.

9 Provision of broadband services and also Internet, e-mail even to passive citizens connected to the entire infrastructure via PSTN based CMN

Referring to Figure 1, the Heraklion demonstrator comprises a CMN (namely “CMN 1 at downtown WLAN”), which interconnects its own users with all other Heraklion users/citizens via PSTN connection. The configuration of this Heraklion CMN creates a hot-spot area based on the WLAN technology. Users belonging to this CMN, provide their own IP data requests/acknowledgements to the CMN over this WLAN link, and from there via the PSTN connection to the entire Heraklion city over the UHF channel.

The appropriate data replies (stemming from an active user/citizen within Heraklion city) are received by this CMN via the UHF channel (CMN 1 at downtown WLAN) and forwarded to the specific users over the WLAN link. Specifically, Internet and e-mail requests are addressed to an ISP provider (located within the WLAN area of another CMN – see figure 1), while requests for broadband services (i.e. AoD, VoD, IP-TV) are addressed to the appropriate active user/citizen (i.e. IP multicaster). The corresponding IP reply data are initially received by this CMN (CMN 1 at downtown WLAN) and then forwarded to the appropriate user over the WLAN connection. It is evident therefore, that in such a CMN, a switching mechanism that will substantiate the asymmetric communication (uplink via PSTN and downlink over the UHF channel) is required.

From all the above cases it comes that the realisation and adoption of such a CMN in Heraklion demonstrator set-offs the capability/potentiality of DSO to enable the provision of broadband services and also Internet, e-mail even to passive citizens connected to the entire infrastructure via PSTN based CMN.

10 Conclusion

This paper presented a DSO approach towards the realization of a Fusion environment that i) confronts the need for synergy between the broadcasting and the telecom operators, and ii) contributes in the discussions concerning the spectrum issues and the Spectrum Dividend exploitation. In this respect, it described and analysed the architecture of an infrastructure that has been developed and is running in Heraklion city (serving as demonstrator for ATHENA FP6507312 IST project) for setting-off the conception adopted for the transition towards the new digital television in UHF. This demonstrator (i.e. a TV UHF channel) provides basic/main/primary services such as digital TV programmes (including the TV programme of the Greek national broadcaster that can received in Heraklion only via satellite equipment – ERTSat), Internet and e-mail access, IP-TV, Off-line television, datacasting and multicasting, to the entire city 24 hour-a-day (even during the Olympic Games 2004 – Heraklion is an Olympic city), proving initially (and at this phase of the project) the validity of the proposed architecture.

Based on this preliminary demonstrator, a set of tests/trials will be conducted concerning the performance evaluation of this infrastructure, its usage and its performance over the services' provision, its effectiveness for professional/business use, the bandwidth management procedure, as well as the encryption procedure. These tests/experiments include trials for QoS of the provided services (ranging from simple/common transmission and reception of the digital MPEG-2 TV bouquet to the provision/access of Internet, e-mail applications, VoD, AoD applications), performance tests on various components and modules, evaluation experiments on the overall infrastructure that this TV channel has created in the city, along with trials concerning the scalability and the adaptability to support forthcoming technologies of such an infrastructure.

11 Acknowledgements

The proposed approach has been adopted by ATHENA (Digital Switchover: Developing infrastructures for broadband access, FP6-507312) project in the Sixth Framework of IST, (thematic priority IST-2002-2.3.1.3 'Broadband for all'), and will be implemented in a medium sized city (Heraklion, Crete, Greece). The consortium partners of ATHENA (distributed across industry, research institutes and universities in Europe) are: NCSR Demokritos Project Co-ordinator (Greece), Space Engineering (Italy), Thales Broadcast and Multimedia (France), Rhode & Schwarz (Germany), Centre for Technological Research of Crete (Greece), Telscom (Switzerland), Rundfunk Berlin-Brandenburg (Germany), T-Systems Nova (Germany), University Politchnica Bucharest (Romania), PRISM-CNRS (France), Temagon (Greece), and University of Bournemouth (U.K).

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