Digital Switchover in UHF: the ATHENA concept for Broadband access

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Abstract—**This paper presents a concept adopted by ATHENA IST-507312 project for the proper adoption of digital switchover (DSO), i.e. the transition form analogue to digital broadcasting in UHF. It anticipates that if DSO is properly adopted, by taking into account the local and networking capabilities of Terrestrial Digital Video Broadcasting standard (DVB-T), it may constitute the vehicle towards the creation of a broadband access infrastructure, which is capable of enabling access not only to digital TV bouquets, but also and most predominant to Information Society services, such as Internet, e-mail, IP-TV, IP-Radio, Video-on-Demand, Audio-on-Demand, etc. Such an infrastructure, which is commonly shared among broadcasters, telecom operators, Internet Service Providers (ISP), active users/citizens who create/manipulate and distribute their own services, constitutes a Fusion environment that is offered to all existing and potential service/content providers for open competition in technological and service level, in content creation and delivery level, in networking business/market field. In this respect it presents the design and architecture of such a Fusion environment that makes use of regenerative DVB-T configuration for providing both digital TV programmes and Information Society services, in Heraklion city, Crete, Greece, while enabling users/citizens to access/participate in this Fusion environment via intermediate communication nodes (cell main nodes – CMN). Finally, based on the adopted architecture, the paper elaborates on the potentialities of the proposed DSO concept to establish broadband access Fusion environment in metropolitan areas.**

Index Terms—**Digital Switchover, Broadband Access, Fusion environment, Spectrum Dividend**

I. 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]-[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

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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:

- 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,
- 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),
- the deployment of an infrastructure that is commonly exploited among 3G and B3G operators and Broadcasters having independent business plans and different user/clients,
- 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,
- the realisation of each active user as a potential service/content provider (spin off activities, e-business),
- 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,
- 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 a test-bed Fusion infrastructure has been set-up and running in Heraklion city. Based on the resulting frequency release when DSO is adopted, Section 3 elaborates on the potentialities of the proposed concept to establish broadband access Fusion environment in metropolitan areas. Finally, Section 4 concludes the paper.

II. 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. The proposed DSO concept is oriented, however, 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).

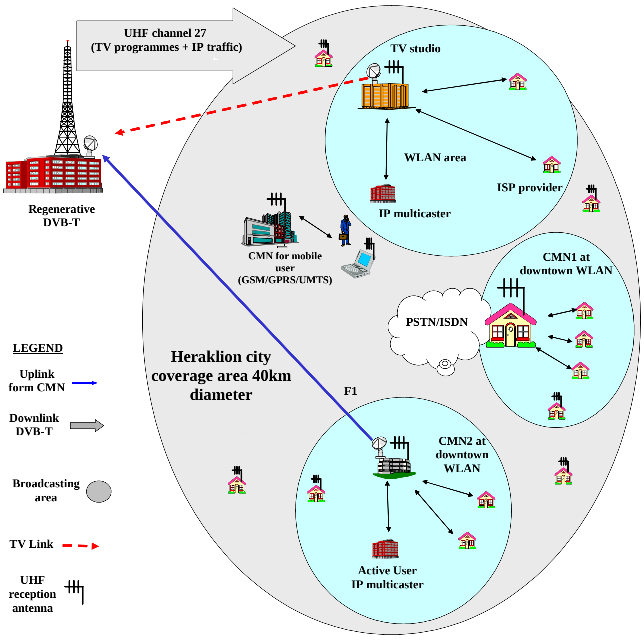

Fig. 1. Overall Architecture

A. *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).

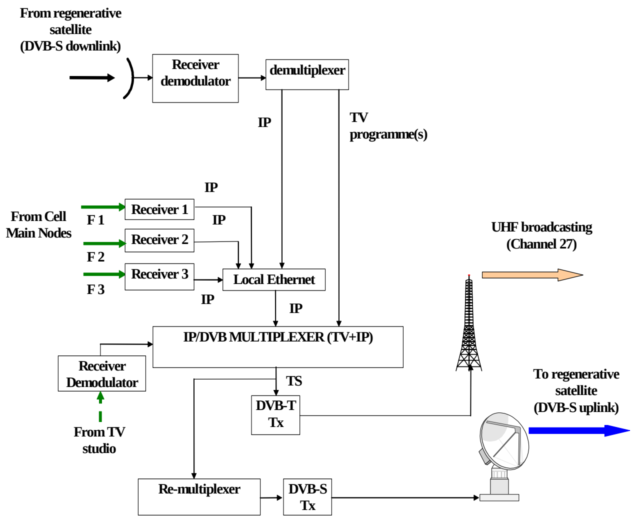

Fig. 2 Regenerative DVB-T configuration

B. *Cell Main Nodes 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. 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":

- The regenerative DVB-T concept
- 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 than the other.

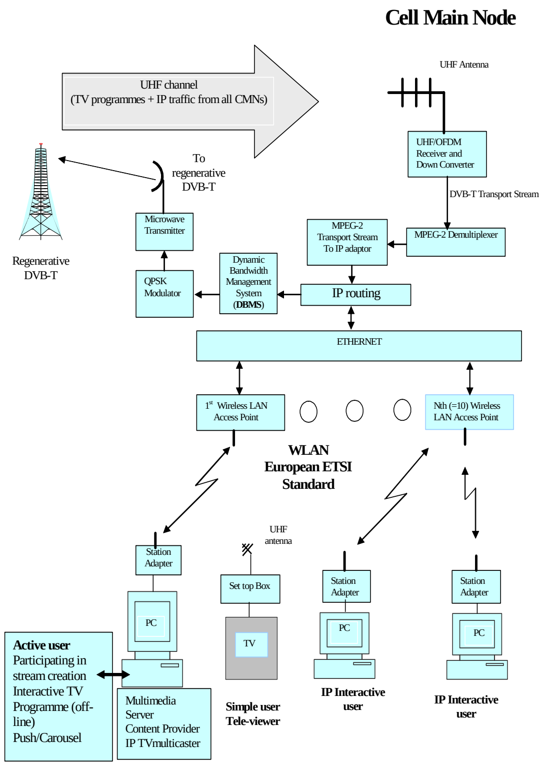

Fig. 3. CMN configuration (WLAN case)

III. Adopting ATHENA DSO Concept for Metropolitan Broadband Access Infrastructures

The above two pillars, which are taking into account the local and networking aspect of the new digital television in UHF (DVB-T), constitute the basis of the proposed DSO concept, which may be applied for the entire VHF/UHF band, i.e. for each 8MHz channel within the range of 47MHz-to-230MHz and 470MHz-to-862MHz.

While this VHF/UHF spectrum proved to be short for current analogue TV broadcasting, the adoption of DSO will result in a Spectrum Dividend, i.e. a frequency release in both VHF/UHF bands.

Taking advantage of this Spectrum Dividend (i.e. the frequency release when DSO is applied) and by building on the above two pillars, a Fusion environment with multi-service capabilities may be released, in a city that has adopted the proposed DSO approach. The broadband access potentialities of such an environment can be underpinned when the "regenerative DVB-T" concept is adopted for the entire UHF band, fully exploiting the Spectrum Dividend in terms of bit-rate. In other words, building on the ATHENA concept, the 60 available analogue UHF/VHF channels may be seen as a virtual medium that provides in a city an aggregate bit-rate of about 1.8Gbps.

The overall architecture of such a broadband Fusion environment (see Figure 4) comprises two core subsystems: i) a central terrestrial transmission point (regenerative DVB-T – RDVB-T) defining a coverage area (of some kilometres radius i.e. 100km) of overlapping broadcasts (several Terrestrial Digital Video Broadcasting transmissions each one in different UHF channel but of identical footprints), and ii) a number of Cell Main Nodes with regenerative capabilities (Regenerative CMN – RCMN) located within the overlapping broadcasts (OB). Each RCMN enables a number of users/citizens (geographically neighbouring the RCMN) to access IP services hosted by the network. The communication between the users/citizens and the corresponding RCMN is achieved via broadband point-to-point or point-to-multipoint links (i.e. WLAN, xDSL, UMTS, optical, etc.) or even custom narrow-band links (i.e. PSTN/ISDN). The RCMN gathers all IP traffic stemming from its users, and forwards it to the central broadcasting point (RDVB-T visible by all RCMNs) via dedicated point-to-point uplinks, wired (i.e. PSTN/ISDN) or broadband wireless (see F1, F2, F3 in Figure 4).

IP traffic stemming from all RCMNs is received by the RDVB-T, where a process unit filters, regenerates, processes and multiplexes them into an MPEG-2 transport stream (IP-multiplexes) along with digital TV programmes (SDTV, HDTV) stemming from the TV broadcaster(s) (TV studio in Figure 4), towards forming one of the final DVB-T "bouquets". This regenerated/combined traffic carried by the specific MPEG-2 transport stream at a maximum of 30Mbps (following the DVB-T standard), is then routed/delivered to the appropriate DVB-T transmitter, in order to be broadcasted to the entire city via the corresponding UHF channel (i.e. channel 27, 29 or 40 in Figure 4). As a result, the total available bit-rate provided to entire city by all DVB-T streams, is a multiple of 30Mbps and the number of the available DVB-T transmitters (i.e. 90Mbps in Figure 4). Each user receives the appropriate IP reply signals indirectly via the corresponding RCMN, supplied to this RCMN via the appropriate UHF channel (DVB-T stream). For these reason, each RCMN receives all DVB-T broadcasts via a single UHF antenna, utilising however as many DVB-T receivers as the DVB-T transmitted streams are (i.e. 3 DVB-T receivers each one being tuned at UHF channel 27, 29 or 40 following Figure 4). Such a configuration creates a unique broadband virtual and common IP backbone (i.e. of a maximum 90Mbps in case of Figure 4), which is provided by all DVB-T streams in UHF, besides being present and available at every point of the entire city via RCMNs. Users/citizens access the provided services (i.e. HDTV-MPEG4, Internet, e-mail, IP-TV, datacasts, VoD, AoD, etc.) via the corresponding RCMN.

In this respect, the DVB-T streams – provided and present at the entire overlapping broadcast are – interconnects all cells which are located within the OB, besides carrying heterogeneous traffic (i.e. SDTV, HDTV, IP, etc.) that is stemming from any user/citizen located within the broadcasting area, which in turn, may make use of any type of access technology or content creation/compression technique. In such a Fusion environment both reverse and forward IP data traffic are encapsulated into the DVB-T streams, along with broadcast/multicast/datacast services thus improving the flexibility and performance of this regenerative, neutral, networking infrastructure.

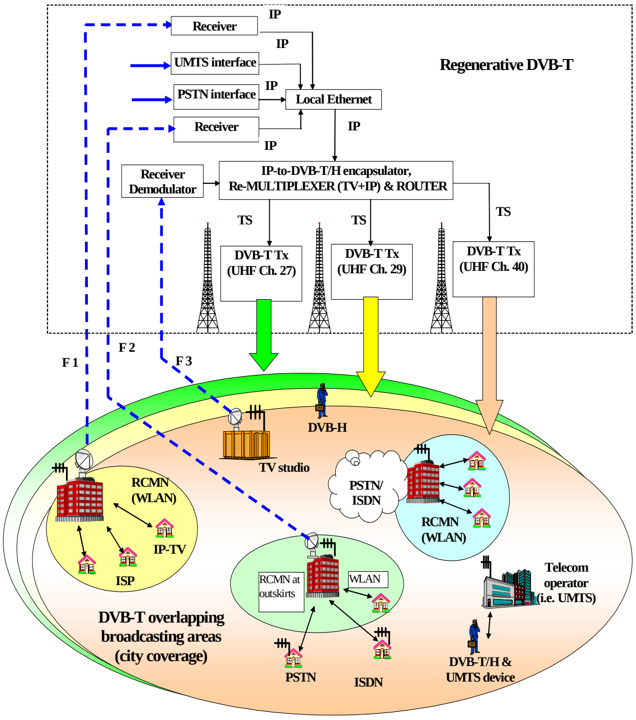

Fig. 4. ATHENA DSO approach for metropolitan broadband access infrastructures

IV. Conclusion

This paper presented the design and set-up of a broadband access infrastructure that realises the digital switchover approach (DSO) proposed by ATHENA IST-507312 project, taking into account the local and networking capabilities of the new digital television (DVB-T). In this respect, it described a Fusion environment that is commonly shared among any existing and potential service/content provider, which makes use of regenerative DVB-T configurations for providing both digital TV programmes and Information Society services, while enabling users/citizens to access/participate in this Fusion environment via intermediate communication nodes (cell main nodes – CMN). Adoption of the proposed DSO concept over the entire UHF/VHF band may constitute the basis for the realization of broadband access Fusion environment in metropolitan areas, when Spectrum Dividend is exploited in terms of "bit-rate" allocation by making use of regenerative DVB-T configurations.

Acknowledgment

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