Exploiting Peer-to-Peer technology for network and resource management in interactive broadcasting environments

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Abstract—This paper presents a novel DVB/IP infrastructure that exploits P2P technology for optimised resource exploitation in interactive services’ provision. Building upon a prototype DVB-T regenerative platform, it presents a decentralised architecture that exploits the broadcasting stream as part of the core/backbone network, providing interactive IP services to rural/urban citizens. Users access the provided IP services via intermediate communication nodes (access network), which are responsible for managing/controlling both uplink and downlink flows. Towards enhancing the scalability as well as the performance of the entire network, the paper studies the realisation of IP overlays by exploiting P2P technology, and proposes a prototype configuration for optimum resource exploitation and increased Service/Bandwidth gain both at the core and access segments. Performance evaluation experiments carried-out under real transmission/reception conditions verified the validity of the proposed architecture, besides outlining fields for future research.

Keywords- DVB-T, P2P, Experiments, Real-Time Transmission

I. INTRODUCTION

In European Union, the broadcasting standard used to deliver digital services over terrestrial links is the Digital Video Broadcasting-Terrestrial (DVB-T) standard [1]. DVB-T can effectively combine heterogeneous services like digital MPEG-2 TV programmes and IP services within the same transport stream (TS), thus contributing towards a unified networking environment, where users can access both broadcast and personalised content (interactive broadcasting).

However, in order to enable DVB-T platforms as part of networking infrastructures providing not only linear but also interactive IP services, the use of reverse path channels is mandatory. In such a scheme the DVB-T links can be used as downlink trunks in a backbone topology [2] for the interconnection of terrestrial distribution nodes, which may utilize various return path technologies (i.e. PSTN/ISDN, WLAN, ADSL, UMTS, GSM) [3] for the uplink traffic. These distribution nodes act as access networks, providing connectivity/interaction to end users over any existing technology (e.g. WLAN, ADSL).

Such an interactive DVB-T implementation has been proposed in [4], where regenerative configurations are exploited for utilizing DVB-T stream as a backhaul network-segment, interconnecting rural distribution nodes, namely Cell Main Nodes (CMN). Experimental evaluation measurements verified that when on-demand services and personalised IP traffic (generated from each distribution node/end-user) contest under the best-effort scheme, the DVB-T downlink is easily overloaded (while uplink and access networks have a negligible utilization), degrading both the system’s scalability and QoS. Although exploitation of DiffServ technology between the regenerative DVB-T platform and each CMN may alleviate these matters [5], optimum system performance still remains an issue, as large part of the overall network resources remain unexploited, especially in the access segment.

In contrast, recent research results have indicated that P2P technology [6] has become imperative for applications of content distribution over highly heterogeneous, best-effort network environments. P2P technology exploits efficient bandwidth monitoring and routing decision mechanisms at the application layer applied among nodes at the edges of the network and are tasked of transferring the content to users,

1 Backhaul is a connection from the local “point of presence” (typically a local exchange building) to the mainline or high-capacity backbone networks, which form part of national and international data transmission networks. This connection is a significant issue for accessing broadband services in small cities and/or in rural areas that are away from the national backbone, since high-capacity networks are normally found in large towns, and obtaining connection to them constitutes a challenge with technological/networking and cost parameters.

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making optimal uses of the underlying “best effort resources” in order to create some basic quality of service conditions. P2P is primarily an end users’ technology that fosters self-deployment [7] and self-organisation [8], while it achieves optimised resource utilisation for the deployed applications and services. In other words, P2P technology has succeeded where QoS mechanisms have failed to be deployed and operate at large scales.

Building upon existing system architectures for interactive broadcasting implementations, it studies the realisation of network overlays in regenerative DVB-T constellations, and presents a prototype infrastructure that exploits P2P technology for optimum recourse exploitation and improved Service/Bandwidth gain, thus contributing towards enhanced system scalability and performance during personalised and on-demand services access.

Following this introductory section, the rest of the paper is structured as follows: Section 2 presents the overall architecture of a regenerative DVB-T platform acting as backhaul for enabling rural/urban users to access on-demand IP services. Section 3 addresses the issue of optimum resource exploitation in this DVB/IP environment, by elaborating on the design and configuration of network overlays with P2P technology. Section 4 discusses on the performance of a DVB/IP P2P aware prototype test-bed, which conforms to the architectural design issues, and validates its capability, while Section 5 concludes the paper and identifies fields for future research.

II. OVERALL ARCHITECTURE OF DVB/IP NETWORK ENVIRONMENT

The overall architecture of an existing DVB-T converged environment [4] is depicted in figure 1. It consists of two core subsystems: a) a central broadcasting point (DVB-T core network), and b) a number of Cell Main Nodes (CMNs) distributed within the broadcasting area.

Each CMN enables a number of users/citizens (geographically neighbouring the specific CMN) to access IP services (see figure 2) that are hosted by the entire infrastructure.

The communication between the users and the corresponding CMN (access network) is achieved via broadband point-to-multipoint links (i.e. WLAN, WiFi, ADSL, etc.). Each CMN gathers all IP traffic stemming from its own users (i.e., file sharing data) and forwards it to the central broadcasting point via dedicated point-to-point uplinks. IP traffic stemming from all CMNs is received by the broadcasting point, where a process unit filters, regenerates and multiplexes it into a single transport stream (IP-multiplex) along with the digital TV programme(s) stemming from the TV broadcaster(s) (TV studio), towards forming the final DVB/IP "bouquet". Each user receives the appropriate IP reply signals indirectly via the corresponding CMN, while receiving custom digital TV programmes (e.g. MPEG-2) via the common DVB-T stream.

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 networking infrastructure. In addition, the cellular conception that is adopted utilises the DVB-T stream in a backbone topology, which interconnects all cells that are located within the broadcasting area. Thus, a unique virtual common IP backbone is created, which is present at every cell via its CMN.

However, in this configuration and when all the end users request the same data (i.e. the same file, video stream, etc), the DVB-T downlink must reserve the necessary network resources for every end-user separately. This redundant network reservation prevents the utilization of the scarce DVB-T network resources for the benefit of different data transfers. By employing a P2P overlay network over the DVB-T infrastructure, we try to resolve this redundancy issue.

III. P2P OVERLAY IN A DVB/IP NETWORK ENVIRONMENT

Following the design approach discussed previously, this section presents the overall configuration of a DVB-T system that utilizes a P2P Overlay (see Figure 3), which address issues of recourse management and network awareness. By using the
P2P technology, we are innervating the end user to fully utilize the network infrastructure by exploiting the available network resources of their “neighbours”.

The overall configuration of a DVB-T system that utilizes the P2P concept for addressing issues of recourse exploitation and management and user self-deployment is presented in Figure 4. In such a scheme, every Cell Main Node (CMN) access network of the DVB-T network is considered as an independent network that utilize P2P users in a DVB-T network.

The P2P users connect to the DVB-T network through a P2P aware CMN, which monitors and routes the hosted users. Every CMN communicate with the other CMNs that exist in the DVB-T broadcast region via the DVB-T core network making use of the reverse path (point-to-point uplink). All the traffic stemming from the P2P-end users is passing through the CMN where the traffic is forwarded towards the central broadcasting point (UHF transmission point). The communication between the active-user and this CMN (access network) is over IEEE 802.11g full-duplex links.

IV. PERFORMANCE EVALUATION OF A P2P-AWARE DVB/IP INFRASTRUCTURE

Following the design specifications that were presented previously, this section elaborates on the implementation of a prototype platform conforming to the proposed architecture, which serves as a test-bed for conducting performance evaluation tests under real transmission/reception conditions. The overall configuration of this experimental test-bed (as depicted in Figure 3) comprises of:

- A DVB-T platform, where the common DVB-T stream is transmitted in channel 40 of the UHF band (i.e. 622-630MHz), utilizing 8K operation mode with 16QAM modulation scheme, 7/8 code rate, 1/32 guard interval and the multi-protocol encapsulation mechanism (MPE) [5] for the distribution of the IP datagrams. These transmission parameters provide a total available downlink capacity of about 20.5Mb/s, according to the DVB-T standard, part of which (12.5Mb/s) was allocated among three digital TV programs (MPEG-2 live and non-live TV broadcasts), while the rest bandwidth was dedicated to IP services (i.e. 8Mb/s).

- A P2P Tracker/Monitor module located at the regenerative DVB-T side, providing information about the availability of content, the RTT time and the location of every peer (end-user) prior to the overlays creation.

- A CMN (namely CMN1 in Figure 5) located in an urban area, providing access to file sharing applications (i.e. a 50Mbyte audiovisual data), hosted by the “active user”. The communication between this CMN and the regenerative DVB-T platform was via a one-way point-to-point link IEEE 802.11g (uplink), while downlink data are received by the CMN over the DVB-T broadcasting stream. The communication between the active-user and this CMN (access network) is over IEEE 802.11g full-duplex links.

- One rural-based CMN (namely CMN2 in Figure 5) located 10 kilometres away from the regenerative DVB-T platform. This CMN serves 5 users exploiting ADSL technology (downlink8048/uplink1024) in the access network, while communicating with the regenerative DVB-T over common PSTN/ISDN lines in the uplink, and over the broadcasting stream in the downlink.
Based on this test-bed, a number of experimental scenarios was designed, where the first one was focused on evaluating the system performance under typical Client/Server applications, i.e. when no P2P overlay is formulated during a file transfer procedure. In this experimental scenario, the users located within CMN2 were requesting the same file hosted by the active-user located within CMN1. The duration of this experiment was chosen to be five minutes, i.e. a period sufficient for the prototype to reach a stable state. Experimental results from this scenario verified that while the downlink resources are heavily utilized, other parts of the infrastructure underutilised and unexploited. More specifically, when the 5 users were simultaneously requesting the same file (50MBytes file size), the 8Mb/s DVB-IP channel in the DVB-T downlink was congested, providing a utilization of 83%, while the utilization of each ADSL uplink (in the access network) was only 3% (request/acknowledgments data). The round trip time in this experiment was measured at about 137ms.

Towards alleviating the DVB-T utilisation and enabling more balanced recourse exploitation among all network segments, in the second experimental scenario the P2P modules were activated, i.e. a tracker/monitor mechanism was activated in the regenerative DVB-T side and the corresponding P2P-client application at the end user’s side. In this respect, transferring the same data-file to 5 end-users as previously, the experimental results indicated an overall reduction in the DVB-T downlink utilisation of about 35% (see Graph 1). This decrement is proportional to the utilisation of each ADSL uplink (in the access network) i.e. 7% of the requested data were transferred over each ADSL uplink channel, instead of the DVB-T downlink, resulting to an overall utilisation of each ADSL uplink of about 77% (see Graph 2).

Quantitative comparison between the client-server and the P2P approaches is depicted in Graph 3, representing the “unique” bytes sent over the DVB-T downlink vs. the number of active peers. More specifically, when only a single peer is active (first pair of bars in Graph 3) the requested 50Mbytes file was carried via the DVB-T downlink, no matter if the P2P modules are activated, similarly to a client-server scenario. On the other hand, when all 5 peers are active (last pair of bars in Graph 3), a total of 162.5MBytes are carried over the DVB-T downlink instead of the 250Mbytes in the client-server scenario, while the rest 87.5Mbytes are provided over the ADSL uplinks (i.e. 17.5Mbytes from each peer). Such a decrement in the DVB-T utilisation may allow the deployment of more services as well as the accommodation of more users, improving therefore the system’s scalability and overall performance.
V. CONCLUSION AND FUTURE WORK

This paper presented a DVB/IP infrastructure that exploits P2P technology for optimised resource exploitation in interactive services' provision. Building upon a prototype DVB-T regenerative platform, it described a decentralised architecture that exploits the broadcasting stream as part of the core/backbone network, providing interactive IP services to rural/urban citizens. Users access the provided IP services via intermediate communication nodes (access network), which are responsible for managing/controlling both uplink and downlink flows. Towards enhancing the scalability as well as the performance of the entire network, the paper elaborated on the realisation of IP overlays, and proposed a prototype configuration for optimum resource exploitation and increased Service/Bandwidth gain both at the core and access segments. Performance evaluation experiments carried-out under real transmission/reception conditions verified the validity of the proposed architecture. Enabling, however, dynamic peers’ selection prior to the overlay creation as a matter of network characteristics (e.g. BER, Jitter, delay, etc.) and specific service/content quality requirements, constitutes a field for future research, aiming at maximum system performance, scalability and guaranteed QoS.

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