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Broadband multimedia on the move with DVB-H

**Georgios Gardikis · Georgios Xilouris ·
Charalabos Skianis · Anastasios Kourtis**

Abstract DVB-H is the newly standardized extension to DVB-T, aiming at the provision of IP datacasting (IPDC) services to mobile terminals. This tutorial paper outlines the structure of an interactive DVB-H platform and presents in brief the technical advances of the new specification. It also discusses some interesting scenarios of interactive and non-interactive services which can be directly deployed with the use of the DVB-H technology either as a stand-alone broadcast network or as a complement to existing cellular (2G/3G/WLAN) infrastructures.

Keywords DVB-H · Cellular/broadcast convergence · IP datacasting

1 Introduction

DVB-T (Digital Video Broadcasting for Terrestrial) was standardized by ETSI in 1997 as a transmission system designed and optimized for terrestrial DTV configurations. Although it was initially designed for stationary use, DVB-T presented an outstanding performance in mobile reception also [10]. To further support the perspective of mobile DTV, ETSI introduced in 2004 the DVB-H specification [2]. DVB-H substantially comprises of a set of

G. Gardikis (✉) · G. Xilouris · C. Skianis
Department of Information and Communication Systems Engineering, University of the Aegean,
GR-83200, Karlovassi, Samos, Greece
e-mail: gardikis@iit.demokritos.gr

G. Xilouris
e-mail: xilouris@iit.demokritos.gr

C. Skianis
e-mail: cskianis@aegean.gr

A. Kourtis
National Centre for Scientific Research "Demokritos", Institute of Informatics and Telecommunications,
Patriarchou Gregoriou str., Ag. Paraskevi, Athens 153 10, Greece
e-mail: kourtis@iit.demokritos.gr

extensions to DVB-T which are oriented to handheld use. DVB-H inherits all the benefits of its predecessor and adds new, mobile-oriented features, focusing on IP datacasting and including better mobility and handover support, adaptive per-service error protection and power saving capabilities.

This tutorial article attempts a brief though thorough overview of the new technology, its technical aspects and its new application perspectives. Section 2 presents the evolution of digital terrestrial and handheld TV and outlines the technological benefits introduced by the DVB-H specification. Section 3 discusses service scenarios which can be supported by the DVB-H technology, including hybrid access methods derived from the synergy between digital broadcast and communication networks. Finally, Section 4 concludes the paper.

2 The evolution of handheld digital television

During the mid-1990s, the MPEG-2 Transport Stream (TS) was world-widely accepted as baseband format for digital television networks. Its structure allows the transmission of encoded digital video and audio streams, along with IP data, organised in a statistical Time Division Multiplex (TDM). The need for an efficient physical layer arose, which would deliver the MPEG-2 TS to the end user terminals via the “difficult” terrestrial channel.

Several research efforts have been conducted around the world to optimise the physical layer for terrestrial DTV. North America adopted the ATSC A/53 system, developed by the Advanced Television Systems Committee in 1995 and based on 8-VSB modulation. In Japan, the Association of Radio Industries and Businesses developed in 1998 the ISDB-T (Integrated Services Digital Broadcasting—Terrestrial) specification for the same purpose.

In Europe, DVB-T (Digital Video Broadcasting for Terrestrial) was standardized by ETSI in 1997 as a transmission system designed and optimized for terrestrial DTV configurations. Although it was initially designed for stationary use, DVB-T presented an outstanding performance in mobile reception [10] also where it outclassed ATSC [13]. However, there were several issues regarding mobile DTV reception that DVB-T could not directly address, such as:

- *Power consumption*. The limited battery time of portable devices poses a restriction in power needs. Indeed, a DVB-T receiving/demodulation/decoding chain is quite greedy, requiring above 1 W of power.
- *Handovers*. Terrestrial specifications assume static receivers, and therefore provide no support for a handover mechanism, as in cellular networks.
- *Various reception conditions*. In contrast to DVB-T, which assumes static indoor or outdoor usage, a mobile DTV system should provide an efficient platform for simultaneous support of numerous usage scenarios: indoor, outdoor, pedestrian, or inside a moving vehicle at various speeds, while optimising transmitter coverage.

Taking in consideration the aforementioned issues and in order to further support the perspective of mobile DTV, ETSI introduced in 2004 the DVB-H specification. DVB-H substantially comprises of a set of extensions to DVB-T which are oriented to handheld use. DVB-H inherits all the benefits of its predecessor and adds new, mobile-oriented features, focusing on IP datacasting and including better mobility and handover support, adaptive per-service error protection and power saving capabilities. At present, DVB-H is the dominant open standard at its field and compliant systems are being deployed around the world, including Europe, the United States and China. A strong competitor of DVB-H is T-DMB (Terrestrial Digital Multimedia Broadcasting), a standard developed in Korea and

Japan, based on the European DAB (Digital Audio Broadcasting). A third player in the field of handheld DTV is MediaFLO (Forward Link Only), a US proprietary technology developed by Qualcomm, which is gaining ground in North America.

The ETSI specification defines DVB-H as a "broadcast transmission system for datagrams." Like DVB-T, it specifies the physical and link layers, along with the service information. A DVB-H-compliant broadcast platform consists substantially of a DVB-T chain, including all the enhancements introduced by the new specification (Fig. 1). Since a broadcast platform has no native support for interactivity, an IP-based cellular infrastructure (like WLAN, 2G/3G) can be employed complementarily to enable for fully interactive applications.

It must be clarified that most of the innovative features of DVB-H, as explained below, are implemented on the link layer and do not affect the DVB-T physical layer. This allows the new technology to exploit all the benefits of DVB-T, including flexible transmission schemes providing from 5 up to 32 Mbps of net capacity, excellent multipath performance due to the use of OFDM (Orthogonal Frequency Division Multiplexing), use of UHF TV bands using 8 MHz channels, and SFN (Single Frequency Network)-based operation.

In order to use the link-layer features of DVB-H, it is assumed that the useful payload to be conveyed consists of IP-datagrams (or other network layer datagrams) which are transmitted within the MPEG-2 Transport Stream, encapsulated according to the Multi Protocol Encapsulation (MPE) protocol. With this assumption, DVB-H becomes a totally IP-oriented system and does not support native MPEG-2 audiovisual streams. It is however

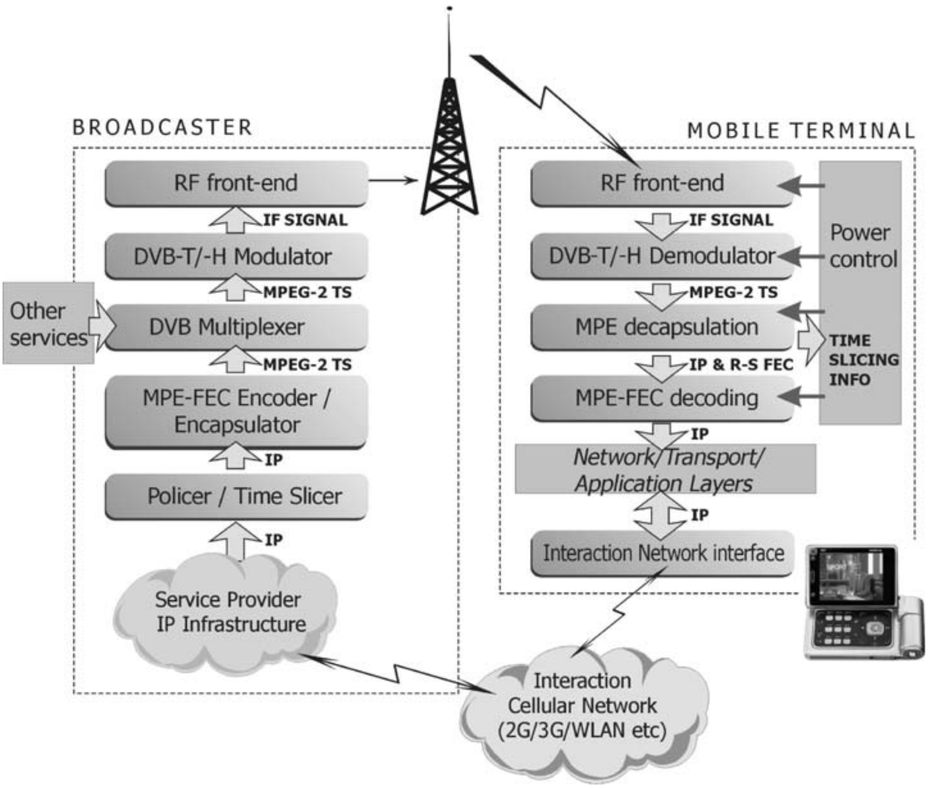

Fig. 1 Block diagram of a DVB-H system

feasible that DVB-H services can co-exist with traditional, DVB-T, MPEG-2-based DTV programs within the same multiplex.

The new features of DVB-H were introduced taking into consideration three principal issues in mobile use: handover/mobility, varying signal reception conditions and limited battery time. DVB-H innovations can be summarized as follows:

DVB-H innovations at physical layer (extensions to DVB-T)

(a) *4K FFT mode*. Native DVB-T operates at two modes (8 and 2K), referring to the number of carriers within the OFDM spectrum. The 8K mode (6,817 carriers) provides a longer symbol period, having a very good performance in large SFNs (Single Frequency Networks) due to better tolerance in long echoes. However, it is unsuitable for fast-moving receivers, since it is very vulnerable to Doppler shift, having relatively small inter-carrier spacing. In a mobile environment, the terminal receives the signal along with a sum of Doppler-shifted replications, created by multipath reflections. The result is a high ICI (Inter-carrier interference). The more closely the OFDM carriers are spaced, the more vulnerable the signal is in high-speed reception. For this reason, the 2K mode (1,705 carriers) provides improved Doppler performance. However, its behaviour in SFN networks is poor. DVB-H introduces the 4 K mode (3,409 carriers) as a trade-off, combining good mobile reception with acceptable performance in small and medium SFNs.
(b) *Additional TPS signalling*. TPS (Transmission Parameter Signalling) bits within the OFDM symbol carry additional DVB-H related information to enhance and speed up service discovery. TPS also carry cell-specific information, which assists the handover procedure in mobile receivers.
(c) *In-depth symbol interleaver*. The DVB-T symbol interleaver requires a certain buffer size both in the transmitter and the receiver. When switching from 8K mode to 4 or 2K, the buffer required for the process falls to 1/2 and 1/4, respectively, since the size of the symbol (in bits) also decreases. DVB-H exploits the unused buffer by increasing the interleaving depth by a factor of 2 (4K) and 4 (2K), thus increasing tolerance to impulse interference. Such type of interference can be caused from sudden discharges, engine ignitions, pulse-operating devices (e.g., microwave ovens) and other electrical appliances.

DVB-H innovations at link layer

(a) *Time slicing*. A basic issue in handheld operation is the limited battery time. This issue is of particular importance in terrestrial DVB reception, where the receiver/demodulator/demultiplexing/decapsulation chain consumes typically 1 W. The time slicing feature of DVB-H aims at reducing the average power consumption by allowing the terminal to know when to expect data and to switch off the receiving chain when not needed (i.e., when the transmitted data are of no interest to the specific receiver). At the broadcaster, prior to encapsulation, IP data belonging to a certain service are organised in TDM bursts. During encapsulation, each IP burst is tagged with a “delta-t” value, which informs the receiver about the time interval until the next burst. This information allows the receiver to switch off until the next burst of data arrives (Fig. 2). Practically, the duration of one burst is in the range of several hundred milliseconds whereas the powersave time may amount to several seconds. A typical power saving up to 90% is expected, whereas this figure depends on the number and the bit rate of the IP services that the terminal is “listening” to. If, for example, we

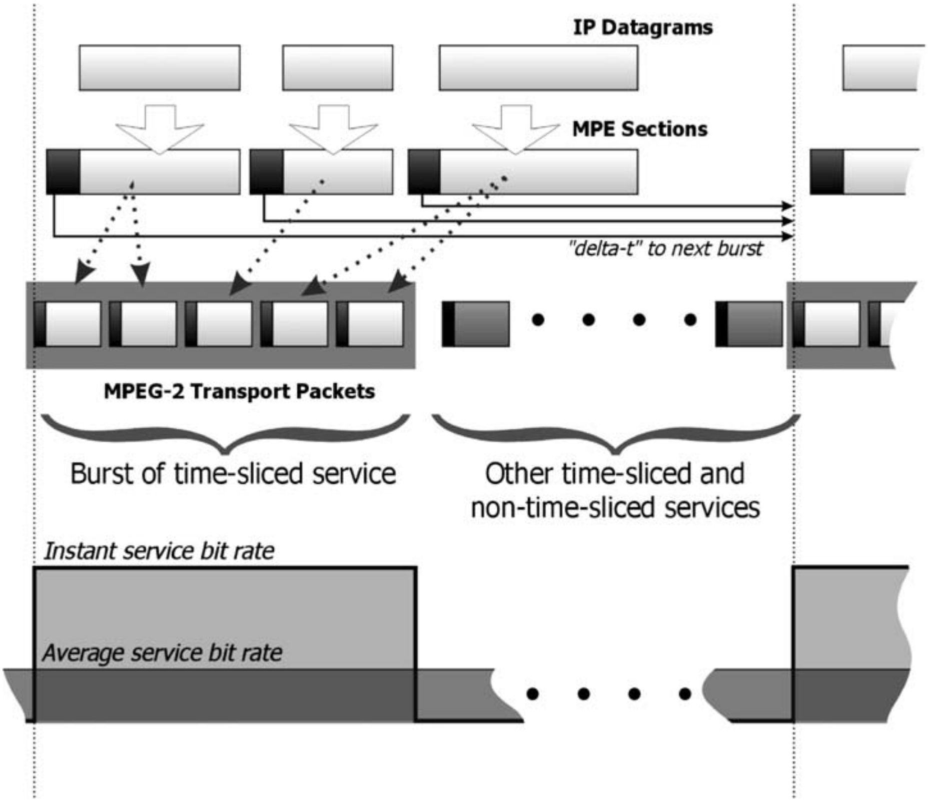

Fig. 2 The principle of time slicing

consider a 10 Mbps multiplex containing, among others, a typical MPEG-4 video broadcast program of 400 kbps, the latter can be organised in bursts of 2 Mb. Each burst lasts 200 ms, and the inter-burst time is 5 s. A power saving ratio of 96% is thus achieved. The real value is somewhat lower, because of the "delta-t jitter" effect, due to which the receiver has to "wake up" a bit before the expected time.

(b) *MPE-FEC*. DVB-T includes two layers of error-protection coding, namely a Reed-Solomon and an inner convolutional coder. These methods protect the transport stream as a whole and have been proven to be very effective. DVB-H introduces an additional transport-layer FEC (Forward Error Correction) layer, prior to encapsulation, which can be applied on a per-stream basis. The MPE-FEC method organises the IP datagrams in a table, column-by-column, and then protects each row of the table with a Reed-Solomon overhead, as shown in Fig. 3. IP datagrams are then separately encapsulated and transmitted from the FEC data. The latter can be discarded by FEC-ignorant receivers, thus making the method backwards compatible. Puncturing, applied on the useful data or the FEC overhead, can result in either stronger or weaker coding, respectively.

MPE-FEC allows the broadcaster to apply a different level or protection on each broadcast IP service, depending either on the importance on the service, and/or on the reception conditions of the terminal(s) to which the service is targeted. Intensive testing of DVB-H, which was carried out by DVB member companies in the autumn of 2004, showed that the use of MPE-FEC can result in a coding gain of some 7 dB over DVB-T [8]. The overhead introduced by MPE-FEC can be compensated by choosing a weaker convolutional code rate, with better results. For example, as Faria et al [4] claim, a convolutional rate of 2/3 in conjunction with MPE-FEC of 3/4 results in a more robust signal than when using a convolutional code of 1/2 alone. However, the IP throughput is the same. The table of Fig. 3 shows some useful total bit rates at IP level for various constellations, convolutional "physical-layer" code rates (native to DVB-T) and MPE-FEC code rates. The values are calculated taking into account the net bit rates of the corresponding DVB-T mode, the MPE-FEC redundancy and the overhead introduced by the MPE protocol and the Transport Packet header.

The calculation assumes that the entire DVB multiplex is devoted to DVB-H services, and that non-hierarchical transmission is used with a guard interval of 1/8 of the symbol period. An 8 MHz broadcast channel is also assumed. Values are shown in Fig. 4 for MPE-FEC rate of 3/4 ("mother code"), 1/2 and 7/8.

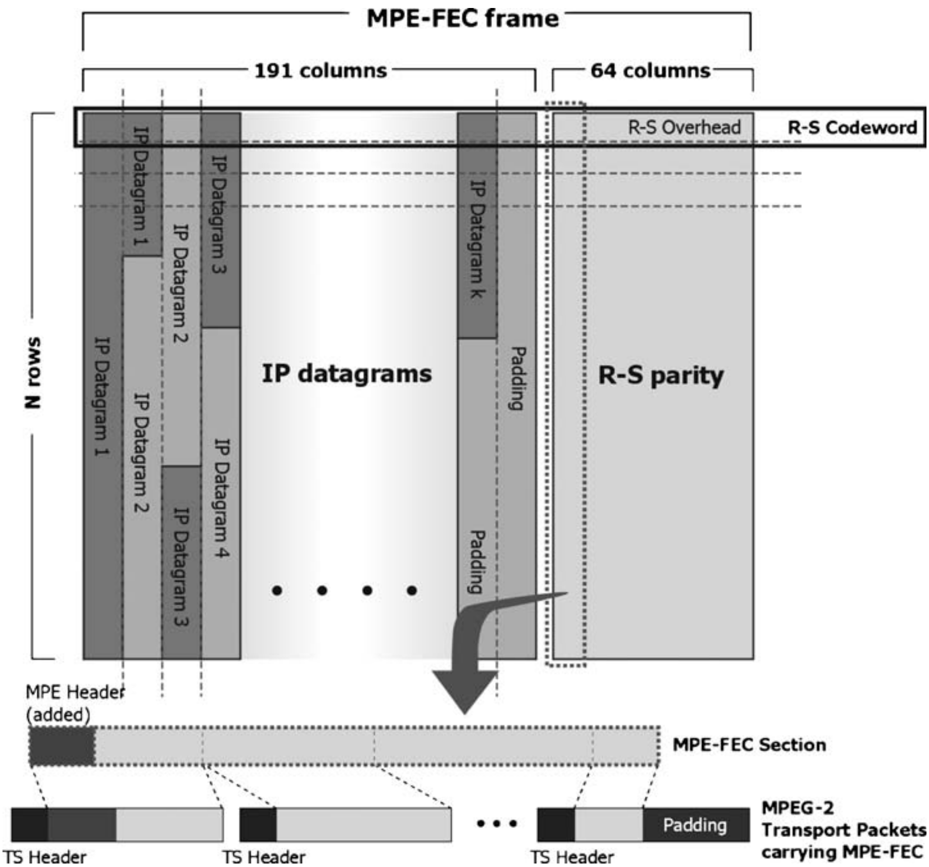

Fig. 3 IP data protection via MPE-FEC

Fig. 4 IP-level useful total capacity (in Mbps) of a 8 MHz multiplex, for different transmission modes and MPE-FEC rates

Constellation	Convol. CR	MPE-FEC CR 1/2	MPE-FEC CR 3/4	MPE-FEC CR 7/8
QPSK	1/2	2,65	3,98	4,65
QPSK	2/3	3,54	5,31	6,19
QPSK	3/4	3,98	5,97	6,96
QPSK	5/6	4,43	6,64	7,74
QPSK	7/8	4,65	6,97	8,13
16QAM	1/2	5,31	7,96	9,29
16QAM	2/3	7,08	10,62	12,39
16QAM	3/4	7,96	11,94	13,94
16QAM	5/6	8,85	13,27	15,48
16QAM	7/8	9,29	13,93	16,25
64QAM	1/2	7,96	11,94	13,94
64QAM	2/3	10,62	15,93	18,58
64QAM	3/4	11,94	17,91	20,90
64QAM	5/6	13,27	19,91	23,23
64QAM	7/8	13,93	20,90	24,39

As ETSI EN 302 304 defines, of the aforementioned features, time-slicing and TPS signalling are mandatory for any DVB-H compatible platform. All other features may be optionally implemented.

3 Services over DVB-H: trends and perspectives

The efficiency and flexibility of DVB-T, enhanced with the new, mobile-oriented features of DVB-H, open virtually innumerable application perspectives for the digital broadcasting market. Since 2004, DVB-H has been deployed on experimental basis across Europe, and extended trials are already taking place in UK, Germany, France, Sweden, The Netherlands, Italy, Finland, Spain and Switzerland. Field trials are focusing on 8 MHz, UHF-based DVB-H downlinks with around 10 Mbps of capacity [8]. Implementation scenarios in the L-band are also being considered. Validation efforts include services based on “anywhere-anytime” access, with portable devices and mobile terminals in cars, trains and other transportation media with very high success. The report of the validation phase is extensively presented in ETSI TR 102 401 [3].

A strong feature promoting the viability and penetration of DVB-H is its backwards compatibility with DVB-T. Given the gradual domination of DVB-T in the terrestrial DTV field in Europe and in other countries, only little modifications are required so that a portion of the DVB-T capacity (possibly unused) can be devoted to DVB-H services. In this way, a digital terrestrial broadcaster could, for instance, “simulcast” a program both in MPEG-2 format (for DVB-T desktop STBs) and in MPEG-4/AVC stream for DVB-H handheld devices, within the same 8 MHz multiplex.

Moreover, very promising service scenarios are expected via the synergy between digital broadcasting and cellular networks [9, 14]. Hybrid DVB-H/cellular handheld terminals are soon to appear in the market (Fig. 5). They are equipped with screens resembling those of cellular phones and PDAs with a very sharp pixel resolution. At the moment, as the official DVB-H site reports (DVB-H, [12]), 33 companies worldwide are finalizing their DVB-H receivers and 42 manufacturers have DVB-H headends commercially available.

Fig. 5 Prototype DVB-H/cellular terminals

Service scenarios which can exploit the capabilities of the new broadcast technology can be discriminated according to the degree of interactivity they require: *non-interactive* (broadcast) applications are unidirectional, as data are broadcast to the terminals, allowing only for local pseudo-interactivity between the user and the terminal. Applications with *low interactivity* include the occasional transmission of small blocks of data back to the broadcaster, via the interaction cellular network (e.g., Tele-voting via SMS or IP). *Fully interactive* applications require a constant, bi-directional, asymmetric flow of data between the broadcaster and the terminal.

Future use cases of DVB-H include, but are not limited to, the following scenarios:

(1) *Digital Television Broadcasting*, the fundamental use of every DVB platform. The innovation introduced by DVB-H is that DTV programs are no longer limited to MPEG-2 encoding, but are conveyed over IP using state-of-the-art encoding protocols, like MPEG-4 or H.264/AVC. Early DVB-H tests of video streams encoded at these formats showed that a pleasant viewing experience can be achieved on a handheld device at CIF resolution (i.e., 352×288) using a rate of around 300 Kbps. This means that a 10 Mbps downlink can accommodate more than 30 simultaneous programs. Moreover, the use of MPE-FEC gives the broadcaster the potential to prioritize the various DTV programs, assigning a different degree of error protection to each of them. Small hard disks or flash memory modules incorporated in the DVB-H terminals can be employed to add PVR (personal video recording) capabilities.

(2) *Scrambled DTV transmission*. Currently, DVB platforms utilize proprietary Conditional Access (CA) methods for scrambling pay-TV content. In DVB-H, where video streams are conveyed over IP, security mechanisms can be elevated to network level. All state-of-the-art authentication and security mechanisms designed for IP networks can be used for encrypting data, including IPsec and multicast key management.

(3) *Push/caching of DTV content* (news, weather forecast, sports flash etc.) “Idle” DVB-H terminals can work in the background to receive broadcast multimedia content and store it locally. The user can then access the content and view it off-line, whenever appropriate. For example, a citizen going to work may use the handheld terminal

when waiting for the bus to view the latest news, or a traveler can watch a cached movie during travel. This feature can be employed at no operating cost for the broadcaster as no bandwidth-per-user is required. Indeed, broadcast platforms like DVB-H are extremely cost- and spectrum-efficient when the same content is to be distributed to a large target group. This is not the case with 3G-based mobile TV streaming, which is quite expensive since additional bandwidth must be allocated for every user joining the service.

(4) *Message Alerts*. A multicast-based alert service can enable users to stay informed about events of their interests such as a "breaking world news" event, a goal which was scored or an unusual stock fluctuation. A text message can be accompanied with audiovisual content. Since the common downlink is used for all customers, this service can also be provided at no cost.

(5) *Enhanced-interactivity DTV programs*. The foundation of all DVB-H services over IP and the use of an Interaction channel via a cellular network allows for new, truly interactive mobile DTV services, including tele-voting, e-shopping, participation in quiz shows, questionnaire filling, via the easy to use handheld devices, all over IP. The built-in cameras of hybrid terminals can also enable the real-time transmission of pictures/sound/video to the broadcaster, thus enabling for a fully interactive television. The "mobile active viewer" scenario envisages that the citizens act as journalists, by providing live feeds—when needed—to the broadcasters, giving instant, on-site news coverage.

(6) *Push/caching of Web content*. A broadcaster may decide to allocate a portion of the DVB-H bandwidth for multicasting popular Web content to an unlimited number of terminals for time-shifted, off-line use, as Stare [11] suggests. Such content may include electronic newspapers, traffic reports, stock quotes or entertainment guides. Given that the memory capacity of the handheld terminals is constantly increasing, it is possible for the broadcaster to allocate e.g., 2 Mbps for this type of service, providing the customers with a complete Web site of 300 pages (assuming an average page size of 50 kB) at their hands after only one minute of transmission! The users are unaware of the caching procedure and are experiencing a very high "virtual bandwidth" as they access the content off-line. Time-slicing can be employed along with proper service information to enable the terminal to save memory and precious battery time by caching only the information in which the user is interested.

(7) *Full on-demand access to data and multimedia content*. If the content in which the user is interested is neither broadcast nor cached, the hybrid cellular-broadcast topology can be used to retrieve the data on-demand. By sending the requests/acknowledgements via the cellular network and receiving the data via the DVB downlink (hybrid asymmetric access), several Mbps of download rate can be achieved [5]. An interesting approach is that of the load sharing between the broadcast and the cellular network: if many users request the same block of information, the delivery is performed over DVB-H so that all users benefit from the common downlink. If there are only a few requests, the data is delivered to each user via the cellular network. In the latter case, the download rate can be much lower, but the wasting of the DVB capacity is avoided [1].

(8) *DVB-H Service Continuity using the cellular interaction network*. In the case that the user roams outside the DVB-H coverage area, a tight broadcast/cellular synergy could enable for the continuity of the DTV service by routing it exclusively via the cellular network at lower quality and, presumably, at higher cost.

(9) *Emergency systems*. In the case of a widespread emergency situation (etc. a natural disaster or a massive terrorist attack), where cellular networks usually collapse, DVB-

H can realise a low-cost and always-on backup broadcast system. A centralized authority can use a DVB-H transmitter to broadcast encrypted or unencrypted material with high error protection to ambulances, police cars etc.

In order that all the aforementioned services, along with many more to come, can be deployed in a uniform basis across different countries, a lot of standardization effort is to be devoted regarding the architecture and software issues of DVB-H platforms. Towards this direction, the DVB CBMS (Convergence of Broadcasting and Mobile Services) working group has set an initial framework for use cases and services of DVB-H [7]. The same group is also responsible for specifying the video and audio formats, the Electronic Service Guide, and the content protection aspects of the DVB-H standard. It has also provided guidelines for the ESG information flow, defined interfaces among the various network entities and illustrated the way the components in IP Datacast over DVB-H work together [6].

There is also a lot of work to be done in the migration of the state-of-the-art features of IP into the world of DVB. The transfer of the benefits of IPv6 in a DVB-H platform can result in a unified architecture for providing dynamic addressing, mobility/handover support and increased security.

4 Conclusion

This paper outlined the innovative features of the DVB-H technology and demonstrated how they can be exploited via numerous service scenarios, tailored to suit the capabilities of a hybrid broadcast/cellular network. The enhancements introduced by DVB-H, combined with the efficiency of the DVB-T-based physical-layer and the synergy with an IP-based cellular network for interaction, opens innumerable application perspectives to this new digital broadcasting system. By offering high data rates, very good mobile performance, flexibility and interactivity, DVB-H brings the dream of “mobile broadband access” much closer to realisation.

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Dr. Georgios Gardikis received his Diploma in Electrical and Computer Engineering from the National Technical University of Athens in 2000 and his Ph.D. from the same institute in 2004. Since then, he has been cooperating with the NTUA Mobile Radiocommunications Lab and the National Center of Scientific Research “Demokritos” in the frame of national and EU-funded research activities, including several IST projects. At present, he is working as an associate researcher in NCSR “Demokritos”, as a technical coordinator of the IST IMOSAN project, aiming at multi-layer management and triple-play services provision in DVB-S.2/DVB-RCS networks. He is also collaborating with the University of the Aegean, conducting a national research project regarding experimental DVB-H deployment. He is a member of the IEEE/Broadcast Technology Society and the Technical Chamber of Greece since 2001.

Georgios Xilouris was born in Athens, Greece in 1976. He received his B.S. degree in Physics from University of Ioannina in 1999 and his M.Sc. in Automation Control Systems and Robotics from National Technical University of Athens in 2001. Since 2002 he is a Ph.D. candidate at the University of Athens, Department of Informatics and Telecoms. He has been granted a scholarship from Institute of Informatics and Telecommunications of NCSR “Demokritos” and he is an associate researcher at the Center for Technological Research of Crete. He has actively participated in various EU-funded projects (MAMBO, SOQUET, REPOSIT, ENTHRONE, ATHENA), with presentations and publications at various conferences, workshops, scientific journals. His current research activities include Next Generation Networks, Satellite Communications, Network Design and IT services.

Dr. Charalabos Skianis is currently a researcher at the Institute of Informatics and Telecommunications of the National Centre for Scientific Research ‘Demokritos’ in Greece and a visiting lecturer in the Department of Information and Communication Systems at the University of the Aegean in Samos, Greece. He holds a Ph.D. degree in Computer Science and a B.Sc. in Physics (Department of Physics). He has been actively working in the area of computer and communication systems performance modeling and evaluation where he has introduced alternative methodologies for the approximate analysis of certain arbitrary queuing network models. He is also keen in traffic modeling and characterization, queuing theory and traffic control of wired and wireless telecommunication systems. His current research activities take upon mobile and wireless networking, ubiquitous and pervasive computing and end-to-end quality of service provisioning in heterogeneous networks environment, convergence of wireless, mobile and broadcast networks. His work is published in journals, conference proceedings and as book chapters and has also been presented in numerous conferences and workshops. He acts within technical program and organizing committees for numerous conferences and workshops and as a guest editor for scientific journals. He is at the editorial board of journals, a member of pronounced professional societies (SMIEEE, ACM) and an active reviewer for several scientific journals. He is an active member of several technical committees within the IEEE ComSoc [TC II; TC CSIM-EiC for the eNewsletter; TC ComSoft], and member of IEEE BTS; IEEE TVT and IEEE CS. He is the founder and E-i-C of the new book series for Troubador Ltd (UK) entitled ‘Emerging Communication & Service Technologies’.

Dr. Anastasios Kourtis received his B.S. degree in Physics in 1978 and his Ph.D. in Telecommunications in 1984, both from the University of Athens. Since 1986 he is a researcher in the Institute of Informatics and Telecommunications of the National Centre for Scientific Research “Demokritos”, currently ranking as senior researcher. His current research activities include digital terrestrial interactive television, broadband wireless networks, perceived quality of video services, end-to-end QoS and real-time bandwidth management in satellite communications. He is author or co-author of more than 80 scientific publications in international scientific journals, edited books and conference proceedings. Dr. Kourtis has a leading participation in many European-Union-funded research projects in the frame of IST/FP5/FP6 (MAMBO, SOQUET, CREDO, WIN, LIAISON, ENTHRONE). He has also coordinated three European-funded specific targeted research projects (REPOSIT, ATHENA, IMOSAN).