INTERNATIONAL JOURNAL OF SATELLITE COMMUNICATIONS AND NETWORKING
Int. J. Satell. Commun. Network. 2007; **25**:409–440
Published online 12 June 2007 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/sat.880

Fusion of digital television, broadband Internet and mobile communications—Part II: Future service scenarios

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SUMMARY

This is the second part of the tutorial paper following the previous tutorial paper describing enabling technologies in digital video broadcasting (DVB) system. The paper presents the current and future operational scenarios for DVB *via* satellite (DVB-S) system. Review of the current state-of-the-art technologies consisting of integration of broadband Internet and mobile communications and integration of broadband Internet and DVB are given. The future operational scenarios emphasize the fusion of DVB systems with other technologies in terms of network fusion and terminal fusion. For satellite service scenarios, it also takes into consideration mobility management and standard quality-of-service mechanism issues, such as integrated services and differentiated services. Several research directions for providing seamless services regardless of network, access technology and terminal in the fusion network are also highlighted in this paper. Copyright © 2007 John Wiley & Sons, Ltd.

Received 22 November 2005; Revised 12 March 2007; Accepted 10 April 2007

KEY WORDS: DVB; DVB-S; DVB-RCS; DVB-S2; mobility management; quality of service; fusion/convergence of services

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Contract/grant sponsor: European Commission

1. INTRODUCTION

The rapid growth in the demand for Internet services has driven the development of digital video broadcasting (DVB) networks to transport and deliver internet protocol (IP)-based services in addition to traditional video broadcasting services. At the same time, mobile communication is undergoing a state of enormous transition towards a broadband mobile communications convergence world, where a competitive way of 'IP goes mobile and mobile gets IP' has been developing for broadband mobile multimedia services [1]. Emergence of varied mobile technologies, increased demand of broadband multimedia service and ubiquitous service requirements by end users, will eventually lead to the worldwide convergence of networks and fusion of technologies including digital television, broadband Internet, mobile communications and some innovative techniques, as shown in Figure 1.

This paper provides a survey of current and future operational scenarios in the fusion of digital television, broadband Internet and mobile communications. Section 2 gives a review of current state-of-the-art technologies, which facilitate the integration of broadband Internet and mobile communications, and integration of broadband Internet and DVB. Section 3 describes the development of future operational scenarios of the DVB system, emphasizing the network fusion and terminal fusion. Mobility management (MM) in a fusion network to guarantee service continuity and fusion of DVB with standard quality-of-service (QoS) mechanisms, such as integrated services (IntServ) and differentiated services (DiffServ), are addressed for satellite service scenarios in Section 4. Finally, future research directions in this field will be discussed in Section 5 before concluding the paper.

2. REVIEW OF CURRENT STATE-OF-THE-ART TECHNOLOGIES

2.1. *Integration of broadband Internet and mobile communications*

The Internet's complexity is growing not only from the mere perspective of protocol development, but also from the architectural and technological viewpoint. Heterogeneous

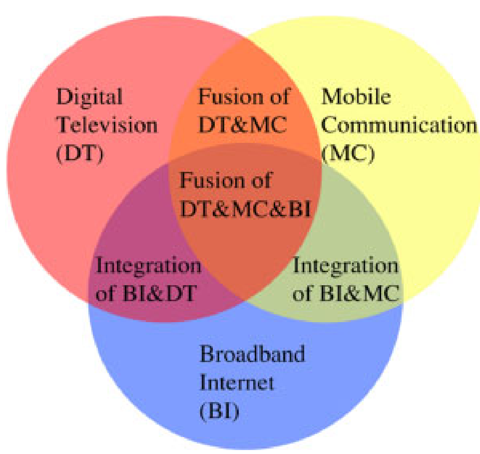

Figure 1. Fusion in digital television, broadband Internet and mobile communications.

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DOI: 10.1002/sat

systems are becoming an essential ingredient to realize ubiquitous services for the Internet. Wireless networks are employed to provide connectivity on the road, satellites for providing wide-band access and wired technologies for all other services, and in particular for the demanding small office-home office (SOHO) world. The integration among the broadband Internet (usually wired) and mobility platforms is not a recent research activity. However, due to the availability of cheaper devices and sophisticated infrastructure, the integration process has become cost effective and as such, widely available to the general population.

As an example, there are two major ongoing efforts for providing wireless coverage over metropolitan areas. On one hand, the IEEE-driven 802.16 standard [2] addresses the 'first-mile/last-mile' connection in wireless metropolitan area networks focusing on the efficient use of bandwidth between 10 and 66 GHz. In addition, it defines a medium access control (MAC) layer that supports multiple physical layer specifications customized for the frequency band of use. The 802.16 is the first noticeable solution, which allows for the integration of the mobility paradigm with the availability of broadband services. On the other hand, cooperative and customized efforts like the one proposed in [3] rely on volunteer effort. In brief, each customer shares a portion of his broadband access, by using 802.11g public hot spot. Even though the last approach suffers a lack of standardization, it is a pioneering approach. It highlights the importance of the wireless local loop for the future integration of broadband Internet and mobile communication.

Future personal mobile communications, also called fourth generation (4G), will allow access to different integrated services. Future platforms will support TV broadcast, high data rates, audio and video conferencing and a rich set of services. However, some existing technologies already offer sophisticated mechanisms to guarantee QoS requirements and exploit reservation and accounting procedures. Besides the technology necessary to exploit mobility and sustain a high data rate, the existing infrastructure also needs to be properly designed and configured. Essentially, the access of a broadband infrastructure raises two main issues: the management of the handover operations and any other operations needed to guarantee network connectivity. Service availability is nowadays guaranteed by the universal mobile telecommunication system (UMTS) infrastructure and by the presence of many 802.11-based hot spots. In the future, there will be a convergence of multi-format devices, which will enable the selection of the most suitable transmission standard to sustain data rates for a given service.

The *de facto* standard to guarantee network connectivity is the IP protocol, which is capable of providing powerful mobility features in IPv4 and also IPv6. Moreover, the specific characteristics of the layer 3 protocols, will also affect important operations, such as multicast. In the future, multicast will be an important tool to serve a large volume of subscribers and to maintain certain QoS requirements. In the latest technologies, such as the 3G of mobile networks, multicast is particularly difficult to achieve because the mobility approach is based on a two-stage IP over IP tunnelling. In this perspective, the 3rd generation partnership project (3GPP) has reviewed the multimedia broadcast-multicast service (MBMS) architecture to allow for more support for multicast transmission, which has been recognized as a key feature for the future integration of broadband access and mobile platforms. The standard, proposes a fully enabled multicast architecture but, with some limitations. The basic limitation is that multicast originators must start a handshake procedure with the MBMS centre and receive an acknowledgement, rather than start sending multicast data in an independent fashion [4, 5]. Moreover the IP multimedia subsystem (IMS) is another global system for network consolidation [6]. It is a standardized next generation networking architecture based on the specification of session initiation protocol (SIP) as standardized by the Internet Engineering Task Force (IETF). Besides SIP, IMS combines a wide range of protocols, which have been developed by the IETF, such as session description protocol (SDP), IP security (IPsec) and enhances them to enable real-time services on top of the UMTS packet-switched domain. IMS aims at providing not only new services but also all other services that the Internet provides using standard IP protocols. A multimedia session between the end users and the interface for service providers are also based on IP protocols, which makes IMS truly convergent with the Internet and the cellular world, where it uses cellular technology to provide ubiquitous access and Internet technology to provide attractive services.

Despite this, another degree of uncertainty is represented by the different kind of mobility depending on the particular application in use or the particular requirements of the signalling framework. For instance, SIP is not designed to deal with mobility, at least not straightforwardly and it needs to be properly tweaked. Understanding them is mandatory in order to build mobile systems integrated with the broadband Internet.

2.2. Integration of broadband Internet and digital video broadcasting

A variety of DVB transmission methods has been used to support interactive IP services, that is, DVB-S [7] or second-generation DVB system for broadband satellite services (DVB-S2) [8] as the forward link and digital video broadcast-return channel *via* satellite (DVB-RCS) [9] as the return link. In the forward link, the moving pictures expert group (MPEG) transport stream packet is used as a container for IP packets; hence, several encapsulation methods are developed to encapsulate IP packets into MPEG cells.

- Multi-protocol encapsulation (MPE) method according to DVB specification [10].
- Unidirectional lightweight encapsulation (ULE) [11] is an alternative standardized encapsulation method for IPv4 and IPv6 datagrams.

The standard MPE scheme for IP over DVB transmission has been widely accepted and implemented, since it was first proposed in 1996. By using the logical link control/sub-network access protocol (LLC/SNAP) encapsulation, it could also be used for transportation of some other network protocols. MPE covers unicast, multicast and broadcast, and is used for applications beyond DVB, for example, by the U.S. Advanced Television Standard Committee (ATSC). The operation of fragmentation into MPEG transport packet for MPE could be subdivided into two steps. The first step is to fragment the data into fixed-size (188 bytes) MPEG transport packets with minimal overhead. A series of transport packets for a given data stream is identified by a user-defined packet ID (PID). The second step is the multiplexing of transport packets from multiple data streams in a single MPEG transport stream (TS).

The ULE standard, which is led by the IETF IP over DVB (ipdvb) working group (WG) is an alternative efficient standardized encapsulation method for transport of IPv4 and IPv6 datagrams and other network protocol packets directly over MPEG-2 TS as TS private data. It is specifically for optimized support for IP in terms of shorter header and IPv6 transport without additional overhead and receiver processing [12]. With less overhead for encapsulation, ULE is beneficial for saving satellite resources and efficient transmission. A comparison between MPE and ULE was presented in [12, 13].

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It is evident that the glue of modern networks is the IP protocol and, in general, the so-called TCP/IP protocol suite. Nonetheless, a lot of devices rely on heterogeneous data-link technologies (L2, i.e. the Layer 2 of the OSI model) over definitely different physical infrastructures (L1, i.e. the OSI Layer 1). In fact, protocols running below the network layer (L3, i.e. OSI Layer 3) are technology dependent, and specific adaptation layers are needed in order to enable the communication between IP (at L3) and underlying MAC protocols (at L2). Well-known solutions are the ATM adaptation layer 5 (AAL5) for ATM networks or LLC for the IEEE 802.1 MAC family, which are commonly adopted in terrestrial networks. ATM adaptation layer (AAL) mechanisms have been also deployed over satellite systems. Other examples of adaptation layer is the MPE defined by European Telecommunications Standards Institute (ETSI) (see [14] for a broader discussion) and ULE defined by IETF, as mentioned above, for the encapsulation of Ethernet frames and/or IP datagrams into MPEG-2 TS.

In general, each IP data flow has to be converted into a technology-dependent stream and vice versa. This conversion requires an operational overhead due to the processing of signalling, packet encapsulation and decapsulation, and, in general, protocol adaptation. The protocol conversion process reduces the throughput of the overall system, both in terms of CPU cycles and protocol overhead. In addition, L3 traffic engineering is commonly adopted to handle IP flows on a per-flow or per-aggregate basis. Traffic engineering is operated by means of reservation and prioritization mechanisms such as resource reservation protocol (RSVP) [15] or DiffServ (per hop behaviours (PHBs) [16, 17]. However, the efficiency of L3 traffic engineering is strongly affected by the adaptation layer between L3 and L2. In fact, L3 entities should be able to access L2 resources in compliance with the QoS profile of each flow. For instance, if a specific L2 solution does not permit any bandwidth reservation on a hop-by-hop basis, a reservation protocols like RSVP cannot provide IP flows with any end-to-end guarantee. As a consequence, the degree of QoS provisioning in a network strongly depends on the interface between technology-dependent and technology-independent protocols (cross-layer protocols).

Issues related to technology-dependent and technology-independent protocols are currently being addressed by ETSI-BSM (Broadband Satellite Multimedia). In ETSI-BSM's QoS architecture for Broadband Satellite Multimedia [18, 19], the adaptation of satellite-independent and satellite-dependent components has to be obtained through the implementation of specific satellite-independent and satellite-dependent adaptation functions (see Figure 2). In that model, the satellite data link layer offers a satellite independent-service access point (SI-SAP) for the communication with higher layers (i.e. IPv4 or IPv6 and so forth). A SAP provide the higher layer with 'primitive functions' to be used in order to access lower layers capabilities and resources; in any case, an entity of layer-$(N+1)$ that requires a service from layer-N is not aware of the way the service is performed. This means that the SI-SAP interface has to be a legacy interface from the IP-layer point of view, but the SI-SAP has to operate a protocol adaptation, which is transparent for the IP end user.

The SI-SAP proposed in ETSI-BSM specify the mapping of IP packets to satellite-dependent functions and vice versa. In the case of satellites supporting ATM, the SI-SAP is the interface that converts IP datagrams into bit streams to be parsed by an AAL that rearranges the bit stream into ATM cells. Furthermore, the SI-SAP handles multiple IP queues and multiple ATM categories (with different queues), and thus provides the interface between the queus at the two layers.

Assuming the case of DVB-RCS satellites, IP flows can be converted into ATM cell flows or encapsulated into MPEG streams [9, 20], while different schemes can be adopted as to the

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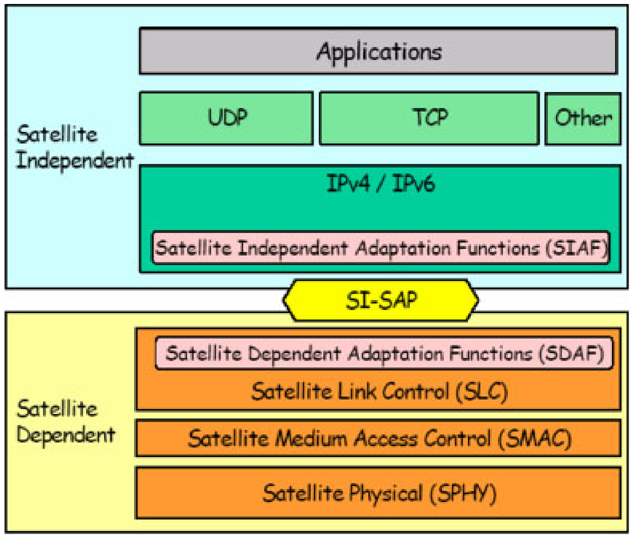

Figure 2. The ETSI-BSM protocol stack.

resource allocation mechanism over the satellite link, or as to the prioritization that the DVB-RCS could offer to L2 connections. The presence of multiple priorities and multiple queues in DVB-RCS is the key to perform a separation between IP flows with different specifications.

It is worth noting that a bi-univocal and QoS-oriented mapping of IP datagrams and MAC frames is not attainable because of the different number of DVB-RCS priorities/queues and IP priorities/classes. However, the case of DVB-RCS satellite networks is particularly relevant, because of the novel possibility to use them as full duplex links, which are suitable for interactive multimedia applications. That is the reason why many works are focused on DVB-RCS technology and its integration with modern Internet architectures (i.e. IntServ and, mostly relevant, DiffServ).

Considering the market of satellite services, there are several products still available that use DVB-S and DVB-RCS technologies to provide remote customer with high-speed Internet connectivity, even though they are not exactly 'low-cost' systems. Most broadcast TV products are based on DVB-S. Using this equipment to provide broadband services requires a terrestrial return channel. Customers can request or purchase data *via* a terrestrial reservation channel and then they will receive data *via* the satellite distribution system, i.e. data will be encapsulated and encoded in the DVB stream. This solution permits the diffusion of high-rate multimedia services, but it offers limited interaction to customers and it does not offer active connectivity to users that do not have at their disposal any wired infrastructure due to inaccessible remote locations. As a matter of fact, this kind of service is an extension of the video distribution on-demand services, which is the application the DVB has been originally meant for. In any case, DVB-RCS is available for backbone extensions and for remote coverage, but devices and usage charges (for the inbound link) are more expensive than the cost for using DVB-S and DVB-S2. Up to date, DVB-S, DVB-S2 and DVB-RCS satellite systems support most of relevant TCP/IP protocols, and also provide special QoS features like TCP accelerators (enhancing TCP performance over satellite path) and bandwidth on-demand management. Commercial solutions developed proprietary applications, user interfaces and database structures. They use secure

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networking through proxy servers and firewalls. So they provide special services like voice over IP (VoIP) or Video on-demand, broadband download services, web portals and e-mail services. Customers are simply required to access services through the provider's web portal; the provider deploys its services through legacy TCP/IP protocols and by means of satellite infrastructures.

Different services require different QoS provisioning methods and, in turn, separate QoS classes. Following 3GPP [21], a network should provide support for four basic QoS classes:

- A 'conversational class', used for real-time applications such as voice and video conferencing, and with the most stringent delay requirements.
- A 'streaming class', used for applications such as video streaming, which can accept some delay variation.
- An 'interactive class', used for services requiring some assured throughput in order to provide good response time, such as web browsing.
- A 'background class', for the remaining applications which do not require priority or stringent guarantees, such as e-mail.

More classes could be provided, e.g. by splitting a given class into two or more subclasses. For instance, the streaming class could be split into 'jitter-tolerant' and 'jitter-sensitive' subclasses. In general, each class is characterized by a set of L3 parameters (i.e. IP performance indicators) like the maximum bit rate, the guaranteed bit rate, the packet loss ratio, the average/maximum queuing delay, the maximum jitter packets could experience. Service providers that operate *via* satellite distribution systems, need tools for (i) separate traffic flows at IP layer (L3) and (ii) enforce a differentiation in the QoS experienced by flows belonging to different classes, by means of L3 and L2 mechanisms. IP technologies are ready to support satellite diffusive and interactive services, with multiple QoS classes. For instance, traffic flows can be separated by means of information conveyed by the IP header. According to that separation of flows, each IP node can enforce a specific policy for each type of flow. It remains to understand how L2 mechanisms can be helpful for traffic engineering purposes, and how and when L3 and L2 mechanisms can be made able to interoperate.

3. FUTURE OPERATIONAL SCENARIOS

3.1. Network fusion

The technology development in information and communication has resulted in the possibility of fusing different system architecture. Unlike a traditional network, where different infrastructures have been specified to meet the specific service requirements, the new innovative and converged network is able to support various services in order to minimize the operational cost and increase the network capacity.

Optimum synergy among the ever-growing DVB, mobile communication and Internet networks will be guaranteed based on IP unified core networks. The IP family of protocols is currently one of the main drivers of digital convergence. In the IP environment, a fusion network will benefit not only from the existing Internet applications, but also from the impulse of the development of new services. DVB-over-IP and IP-over-DVB are currently being developed and standardized. The former refers to the delivery of digital television services over

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broadband IP networks. Typically it will be over a cable network so the supplier can achieve the bundling of services including VoIP and telephony, as well as Internet with the digital television service. The latter, IP-over-DVB, is the delivery of IP data and services over DVB broadcast networks. It takes the advantage of DVB wideband data delivery systems to deliver IP-based services such as file transfers, multimedia and Internet.

DVB is addressing the technology development with respect to mobile communication in terms of synergetic utilization of DVB and cellular (GPRS, UMTS) systems in the DVB *Ad hoc* Group (AHG). Service convergence and network cooperation between DVB/UMTS/GPRS platforms are the ongoing activities within AHG. The DVB-UMTS architecture is applicable to all system and service implementations and is intended for use by implementers of both systems and services. In addition to 3G networks, wireless local area network (WLAN) systems that are playing a more important role in wireless communications, is taken into account in DVB activities. Network architectures of these aforementioned DVB-cellular and DVB-WLAN operational scenarios are further elaborated below.

- *DVB-S and UMTS integration*: DVB-S could be used for broadcast/multicast wideband data delivery *via* the gateway GPRS support node (GGSN) of a UMTS cellular network, which will further distribute the information to mobile users (Figure 3).

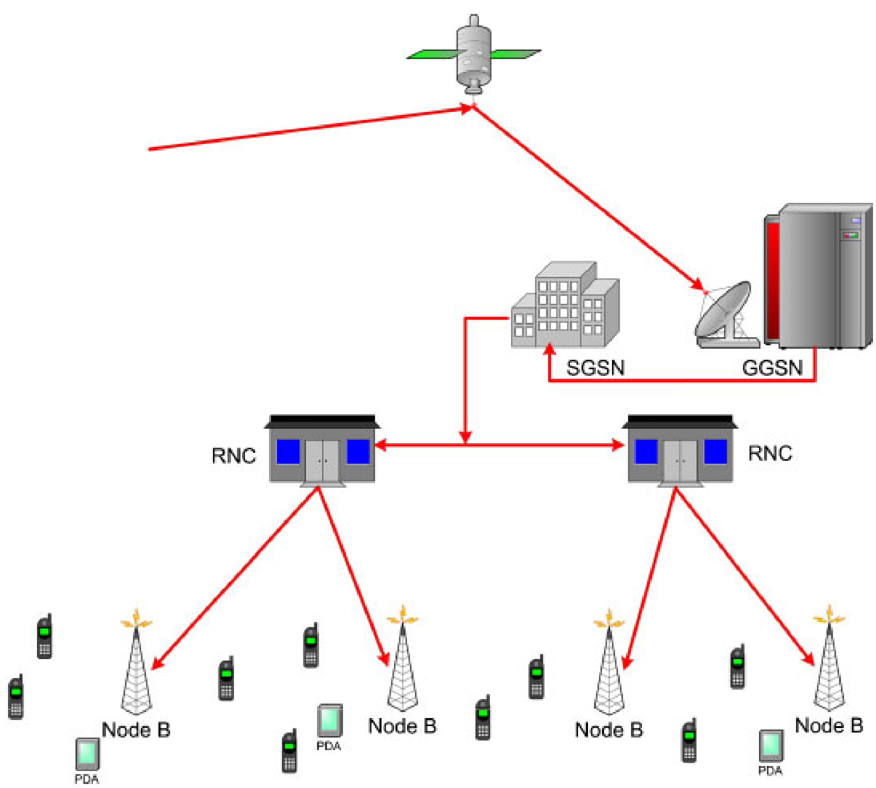

Figure 3. DVB-S and UMTS integration.

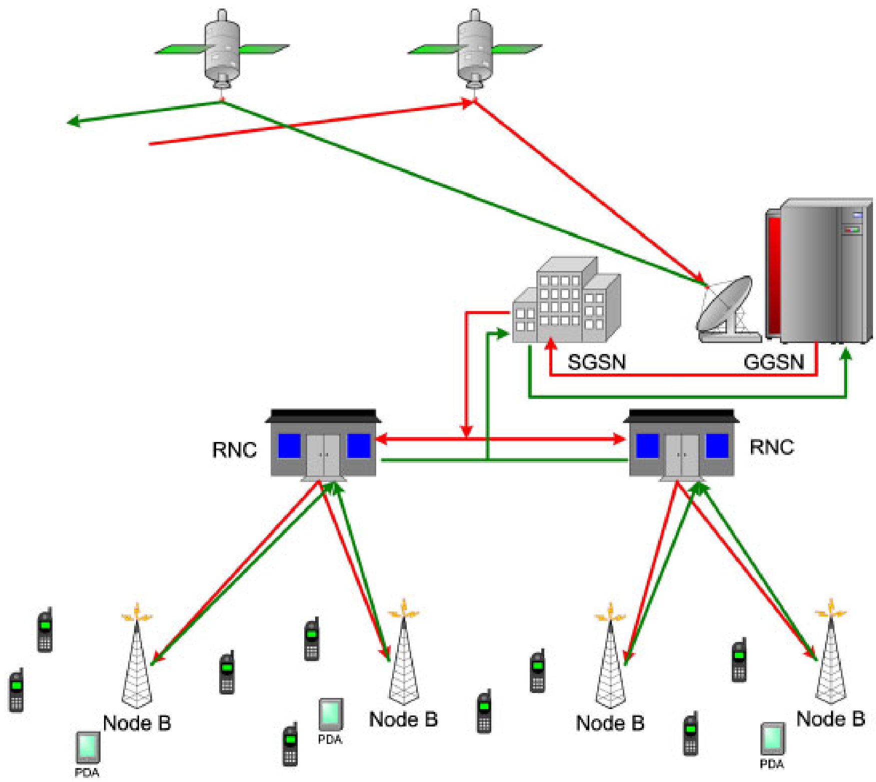

Figure 4. DVB-RCS and UMTS integration.

- *DVB-RCS and UMTS integration*: The UMTS network could also be used for the return path, given that the GGSN is equipped with a DVB-RCS interface (Figure 4).
- *DVB-S and WLAN integration*: WLANs can also exploit DVB. For example, all hot spots in an airport could be connected to a central node, equipped with a DVB interface for the delivery of broadband services to mobile users. Moreover, WLAN standards support communication speeds approximately equal, or even higher, than DVB, so WLAN users could take advantage of all the available bandwidth and benefits that DVB offers. This could also be extended to multihop WLANs, or *ad hoc* networks; however, these networks have less bandwidth available, due to routing problems that have to be solved (Figure 5).
- *DVB-H Deployment Scenarios*: As digital video broadcasting-handheld (DVB-H) has been built upon the existing digital video broadcasting-terrestrial (DVB-T) standard, hence it can be easily introduced with a few modifications in the existing DVB-T network. When DVB-H is deployed in an existing DVB-T network, the bit rate for IP services can be reserved either by multiplexing or by using hierarchical modulation thereby giving two methods of network transition. On the other hand, if there is no bandwidth left for DVB-H services, a DVB-H dedicated network should be built [22].

Figure 6 shows the scenario where DVB-H IP services are established using the existing DVB-T system by directly inserting into the multiplexer. A timeslice-capable IP encapsulator needs to be

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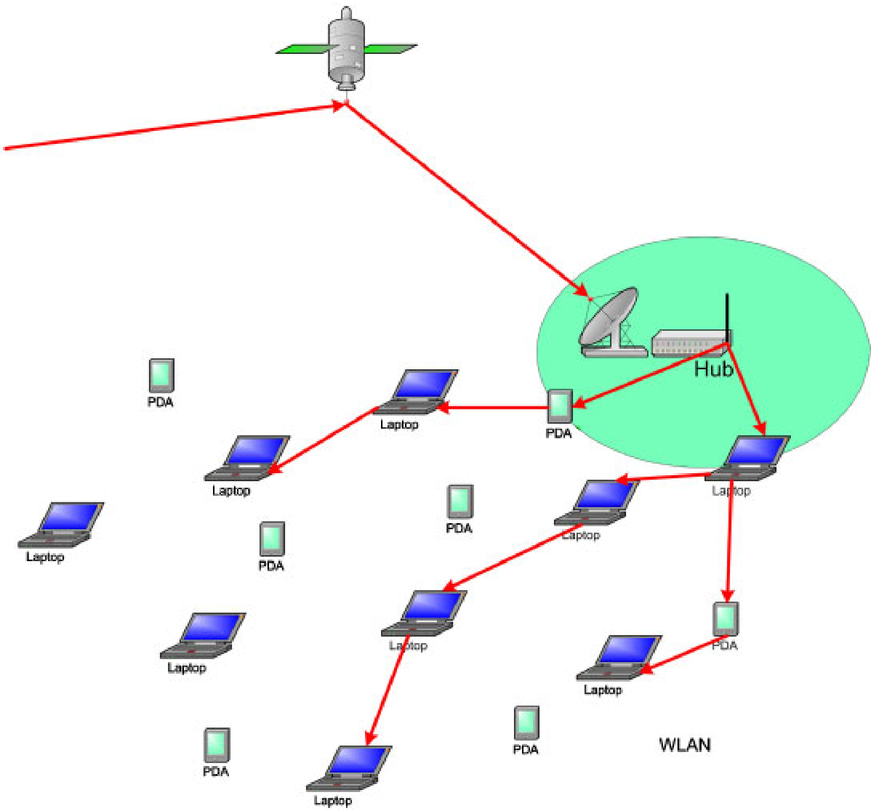

Figure 5. DVB-S and WLAN integration.

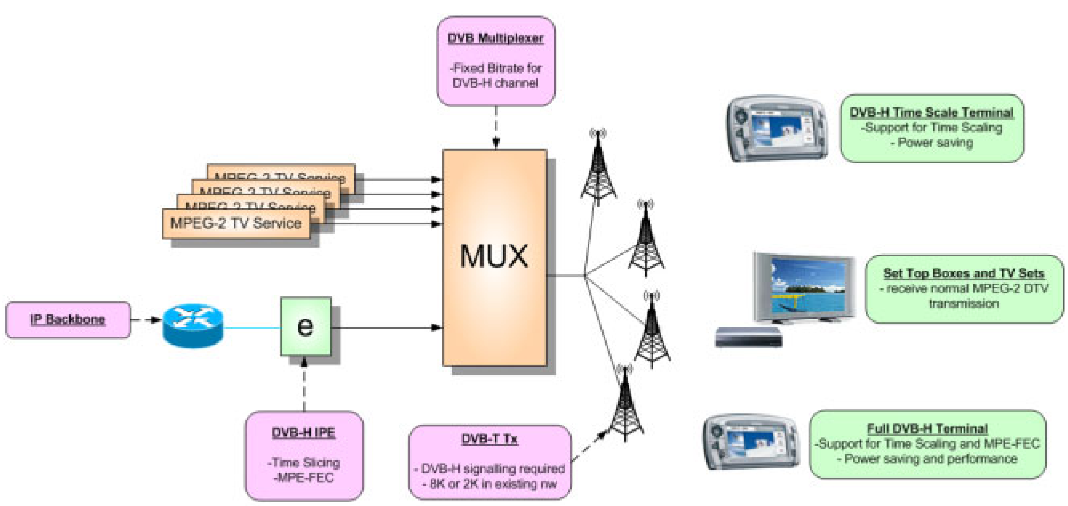

Figure 6. DVB-H deployment in existing DVB-T networks with multiplexing.

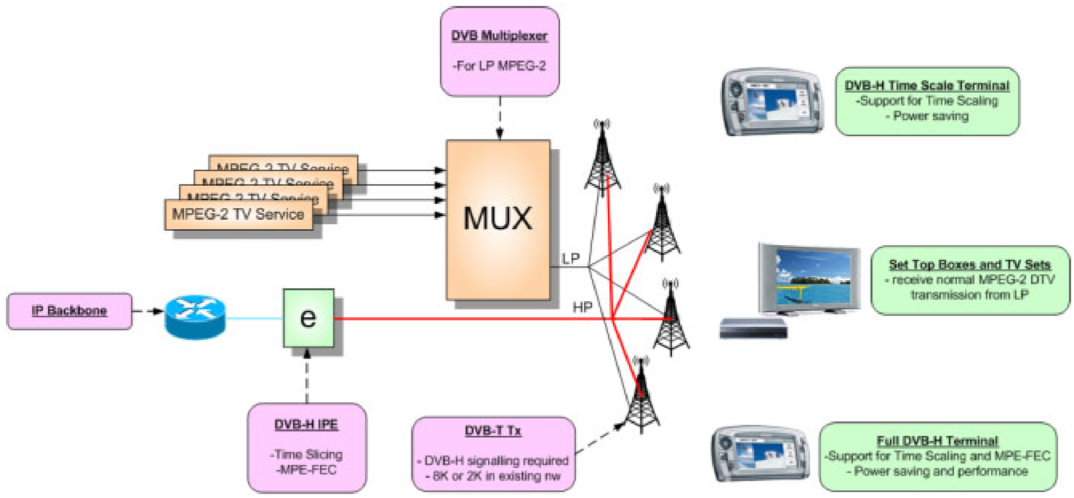

Figure 7. DVB-H deployment in existing DVB-T network with hierarchical modulation.

connected to the last-hop multiplexer, which is ideally located in each coverage area (MFN or SFN), and a fixed amount of bitrate would be reserved for the DVB-H services.

Figure 7 shows the scenario where the DVB-H services are deployed in an existing DVB-T network using hierarchical modulation where the IP services are inserted in the high priority (HP) stream of the DVB-T modulator were existing 2K or 8K modulators are used. A new TS distribution network for the HP stream is needed as well as the IP encapsulator with DVB-H capability. As the IP services is not inserted into the multiplexer in this scenario, the jitter and ID management issues that apply to the multiplexing scenario do not apply to this scenario. There can be separate sets (though mutually dependent) of modulation parameters for fixed (DVB-T) and mobile (DVB-H) reception, leading to more optimal bandwidth usage.

Figure 8 shows a dedicated DVB-H network for IP services. A dedicated DVB-H network is one in which DVB-H services do not share the TS multiplex with existing DVB-T services.

3.2. Terminal fusion

The ability to handle ubiquitous and seamless communications, enabling users to access a multitude of services and networks over multiple air interfaces anytime and anywhere, is the user requirements for the terminals of 4G mobile systems. In other words, the terminals are requested to support multi-band and multi-mode capability, and be able to handle a variety of contents and services such as broadband Internet, mobile communications, digital broadcast and new advanced services. Taking the economics and practical use into consideration, an optimal combination and convergence of latest technologies and consumer devices is essential. Fusion of the terminals is based on end-user requirements and service experience.

A variety of wireless transmission techniques incorporated into the multi-mode terminals is beneficial for providers to service legacy customers as well as offer new advanced services in future mobile communications. A multi-mode terminal should support at least portions of evolving technologies as well as existing ones for backward compatibility, such as radio

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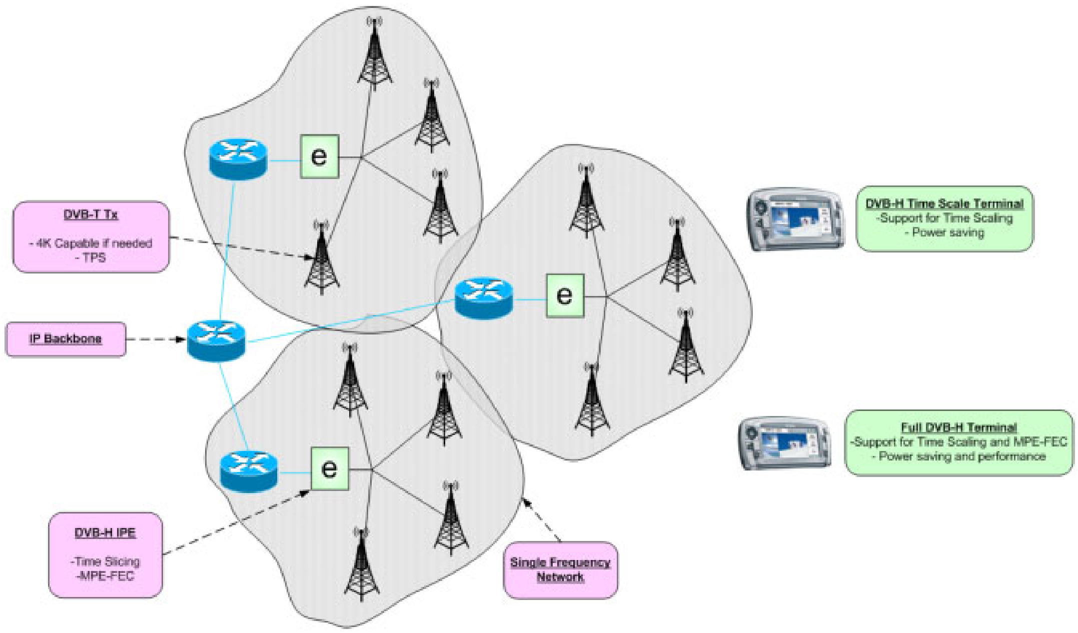

Figure 8. Dedicated DVB-H network deployment.

transmission techniques (e.g. broadcast—DVB/DAB (digital audio broadcasting), WLAN—IEEE802.11 a/b/g/n, WPAN (wireless personal area network)—Bluetooth/Zigbee/UWB, WMAN (wireless metropolitan area network)—IEEE 802.16 a/e), optical transmission techniques (e.g. infrared data association (IrDA)), contactless IC cards and IC tag techniques for radio transmission between terminals and peripheral equipments. However, competition, confusion and technical challenges would come along with the fusion of the transmission techniques. Currently some standards are competing against one another, which will eventually phase out some techniques due to performance and market-related factors in the future [23]. Solutions for several technical challenges, such as: (a) frequency sharing among multiple air interfaces; (b) dynamic frequency assignment; (c) optimized use of spectrum (appropriate service, suitable access network with correct frequency band); (d) seamless connections between different systems; (e) bottlenecks through co-operative networks; (f) end-to-end multi-system wireless techniques *via* multiple modulation schemes/protocols/frequencies; (g) reception of mobile digital broadcast service; (h) use of software defined radio; etc. are required [23].

Many research activities investigating the deployment of future multi-function and multi-standard terminals have resulted in fruitful achievements. The foundation of integration of wireless transmission techniques into a mobile terminal has been established, and different types of multi-mode handsets have already been commercialized by many manufacturers, e.g. the dual-mode WCDMA/GPRS/GSM handset and triple-mode handset that enables seamless roaming between WCDMA/WLAN/bluetooth. The recent launch of unlicensed mobile access (UMA)/WLAN handsets marks a beginning of an industry trend in fixed-mobile convergence. As a result of MEDEA+ A107 4G-radio project, the first 4G terminals are now available to handle worldwide 2G/3G services, as well as providing WLAN and bluetooth connectivity, FM radio and even DVB reception [24].

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Provision of adequate services to end users through integration of technology also depends on mobility and availability, and this brings along several new challenges. One of the main challenges of B3G is seamless handover to guarantee unperceived and continuous service and quality during a terminal's intra-roaming/inter-roaming or switching between networks. When a terminal is in different application environments with different mobility, it could switch between different wireless communications networks, that is, to switch from a current network to another one with relatively high data rate and low price. In terms of standardization, IEEE 802.21 is the developing standard to address issues of seamless handover and interoperability between heterogeneous networks including both 802 and non-802 networks, while 3GPP system architecture evolution (SAE) is working on the same to achieve mobility within the evolved access system. OFDM and generalized multicarrier (GMC) could be adaptively applied for terminal mobility. The OFDM technique is more feasible for a system with relatively low mobility (i.e. the Doppler shift should be lower) and small time delay spread. GMC is suitable for a high-mobility environment or where the Doppler shift and time-delay spread are large [25].

Reconfigurability of software defined radio is widely seen as one of the enabling technologies for the B3G communications systems. Software defined radio allows a single terminal to support multiple systems using different spectrum bands or different radio transmission schemes through rewriting of software. Research and deployment of software defined radio is actively promoted as an essential technique to realize a seamless mobile communication environment and is being pursued within many research organizations/standardizations bodies, for instance, the software defined radio forum, end-to-end reconfiguration (E2R), working group 6 (WG6) entitled 'reconfigurability' of the Wireless World Research Forum (WWRF), the Object Management Group (OMG), etc. [26–29]. Work on cognitive radio could lead to further enhancement of software defined radio, while several technical challenges need to be solved for the practical implementation of software defined radio, e.g. software-based multi-mode modulation/demodulation techniques, multi-band transmit/receive techniques, device optimization for noise/power, development of dynamically reconfigurable processors and techniques for secure rewriting of software, etc.

Mobile terminals with five senses detection are expected to become available around 2010 or beyond [30], as fingerprint technologies have already been adopted for authentication in some terminals for commercial use. Issues of precise detection of senses and development of a coding standard for five-sense information are to be solved [30]. Technologies of display, man–machine interface, battery, sensor and security should be improved for terminals of future communication systems. Several sufficiently spaced antennas integrated in the terminal and higher processing ability are required in order to apply multiple-input-multiple-output (MIMO) techniques to improve the data rate and performance.

4. SATELLITE SERVICE SCENARIOS

4.1. *Fusion of digital video broadcasting and Internet QoS*

4.1.1. Reference network scenario for QoS-oriented cross-layer interoperation. In the following sections, a GEO satellite inter-worked with terrestrial nodes are considered for a QoS-oriented cross-layer interoperation. The satellite is endowed with DVB-RCS technologies, while ground stations are satellite terminals with DVB-RCS transceivers, namely return channel satellite

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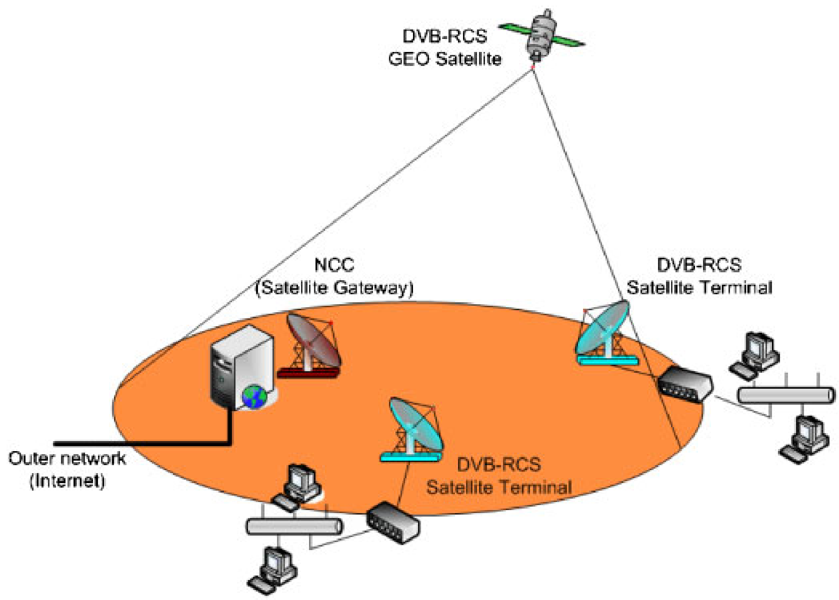

Figure 9. Network scenario.

terminal (RCST). As a consequence, the satellite channel can be modelled as a common asymmetric link. In particular, the DVB-RCS return link is shared among different users by means of a multiple frequency-time division multiple access (MF-TDMA) technique.

The reference network scenario is depicted in Figure 9. The picture represents a DVB-RCS satellite and its coverage area (i.e. for the sake of simplicity, a single satellite with a single spot beam is adopted). The intelligence of actually deployed DVB-RCS satellites is concentrated on two specialized ground stations: the network control centre (NCC) and the RCST. The NCC operates as a gateway to the Internet, and the core of the satellite network for management issues. Each satellite terminal can provide connectivity to one or more users located in a LAN, using TCP/IP protocols. For simplicity, only the communications between satellite terminals and NCC are considered here. Inter-RCST communication can be also provided through a paired connectivity established between each RCST and the NCC (that also acts as a hub). Direct inter-RCST connections should be soon available, but for signalling purposes, since L2-signalling has to be parsed by the NCC.

4.1.2. QoS in a DVB-RCS system. The DVB-RCS bandwidth is shared among different satellite terminals, with possibly different requirements in terms of capacity and delay sensitiveness. Upon a login phase, connections are created between RCST and satellite in order to establish a communication channel that is managed by the NCC. During the connection lifetime, bandwidth is requested by the RCST and assigned by the NCC through five capacity categories [9]:

- continuous rate assignment (CRA);
- rate-based dynamic capacity (RBDC);

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- volume-based dynamic capacity (VBDC);
- absolute volume-based dynamic capacity (AVBDC);
- free capacity assignment (FCA).

L2 services offered by the DVB-RCS node represent the building blocks for the deployment of network-wide services, since they allow resource reservation (in a strict or loose fashion) for the implementation of point-to-point bearer services. Similarly to IP classes, these L2 bearers also exploit the availability of (i) separate queues and (ii) priority-based scheduling between queues. Therefore, a way to differentiate the service offered by a DVB-RCS node consists of tuning of the queuing and scheduling systems for packets coming from the IP layer. In fact, it is possible to set up different physical queues and determine priorities between queues by means of a pre-allocation of hardware resource to each single queue. Hence, traffic offered to a DVB-RCS is transported accordingly to specific 'profile classes' (PCs) that perform differently as to delay and loss characteristics. Actually, this is the only QoS support offered by a DVB-RCS segment in addition to the admission control functions. The different PCs are meant to provide significantly different levels of service, and the envisioned applications range from e-mail to tight real-time video and voice applications.

In particular, three QoS parameters are considered, and six PCs are identified for the DVB-RCS satellite network on the basis of significant combinations of the QoS parameters. Actually, a different number of queues could be provided; here a six-queues architecture is referred in order to support the set of traffic classes, envisioned by ETSI in [31]:

1. real-time priority traffic;
2. variable rate priority traffic, no jitter tolerant;
3. variable rate priority traffic, jitter tolerant;
4. jitter tolerant priority traffic;
5. other priority traffic;
6. best effort.

In accordance to these six categories, or classes, six PCs are defined in Table I. Based on the definition of these classes, the QoS parameters used in the system are as follows:

- The maximum packet transfer delay, computed as the time to move a packet between the extremities of the satellite link. (Delay are accounted for a duration of the order of hundreds of milliseconds or also seconds, since the adopted satellite is in a geostationary orbit, and it takes about 120 ms to traverse the radio channel.)
- The peak-to-peak delay variation (jitter), expressed as the maximum jitter experienced in the satellite link.
- The packet loss ratio (PLR).

4.1.3. QoS-aware interworking of DiffServ, IntServ and DVB system. This and the following subsections are devoted to the mapping between QoS service models presented above. If an IP architecture equipped with QoS-aware mechanisms includes a satellite hop, two issues have to be addressed: (i) the mapping of IntServ services on DVB-RCS PCs and (ii) the mapping of DiffServ classes on DVB-RCS PCs.

When a generic IP/DVB-RCS mapping requires a connection set-up, or a resource reservation, the DVB-RCS MAC requires the knowledge of three main parameters: the

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Table I. DVB-RCS network profile classes.

Profile class	Delay	Jitter	PLR	Application example	Recommended capacity allocation method
1	Highly sensitive (hundreds ms)	Highly sensitive (some tens ms)	Loosely sensitive ($\leqslant 10^{-3}$)	Voice-based	CRA
2	Sensitive ($\leqslant 1$ s)	Highly sensitive (some tens ms)	Sensitive ($\leqslant 10^{-4}$)	Real-time TV-cast, Interactive TV	CRA
3	Sensitive ($\leqslant 2$ s)	loosely or not sensitive	Highly sensitive ($\leqslant 10^{-6}$)	Real-time transaction data	CRA+RBCD+ FCA
4	Loosely sensitive (few seconds)	Not sensitive (no upper bound)	Sensitive ($\leqslant 10^{-4}$)	Web browsing, Interactive games	CRA+RBDC+ FCA
5	Loosely sensitive (some seconds)	Not sensitive (no upper bound)	Highly sensitive ($\leqslant 10^{-6}$)	File transfer	CRA+RBDC+ AVBDC+FCA
6	Not sensitive (no upper bound)	Not sensitive (no upper bound)	Not sensitive (no upper bound)	e-mail, fax	AVBDC+FCA

priority class, the peak data rate (PDR) and the sustainable data rate (SDR). Following the description of Table I, and in particular the rightmost column:

- priority is strictly needed;
- PDR is needed for CRA in case of PC1 and PC2, and for RBDC when PC3–PC5 are used;
- SDR is used by CRA for PC3–PC5;
- VBDC and FCA do not require parameters.

An additional parameter that could be adopted for impulsive traffic flows, is the maximum burst size (MBS). MBS could be specified for PC3–PC5. Conversely, MBS is not significant for PC1 and PC2, because of the delay jitter intolerance, and for PC6, where no specifications are needed.

Results presented in following subsections are based on the research activity carried out in the frame the ESA ARTES project 'Integrated Resources and QoS Management for DVB-RCS Networks' [32]. Guidelines to mapping in terms of PCs (including QoS parameters) and traffic parameters between IntServ or DiffServ service model and DVB-RCS service model are provided.

4.1.4. QoS-related mapping between IntServ/RSVP and DVB-RCS. In an IntServ network, a data flow identifies a set of packets belonging to a 'session' which is specified by IP address of sender and receiver, the transport-layer protocol type, the port number of the destination, and a specific set of QoS parameters are associated with each session [33]. The IntServ model includes two types of service targeted towards (i) real time and (ii) resource consuming traffic applications. These are, respectively, the so-called guaranteed service (GS) and controlled load service (CLS). In parallel with these two services, the default best effort (BE) service can be provided. GS is intended to support real-time applications with tight delay requirements. QoS guarantees are provided through a reservation protocol that tunnels into IP packets any reservation messages, and also by means of per-node resource checking and reservation. The commonly adopted reservation protocol is RSVP [34].

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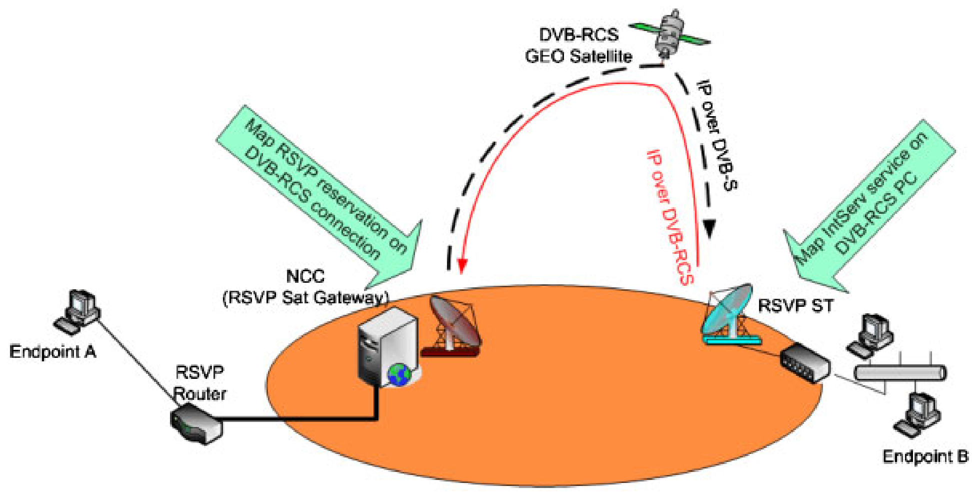

Figure 10. IntServ-aware DVB-RCS satellite communications.

Figure 10 shows an IntServ-compliant network operation, where DVB features are exploited for network-to-RCST flows (downstream over DVB-S) and RCST-to-network flows (using DVB-RCS as upstream). The satellite segment of the flow path is emphasized in the figure. Due to DVB-RCS adoption, the RCST terminal is in charge of mapping IntServ flows belonging to a given service, on DVB-RCS streams with a proper configuration of parameters. The NCC is in charge of managing reservation procedures triggered by RSVP message exchange. Therefore, the satellite terminal could trigger NCC operation *via* DVB-RCS signalling (not shown in the figure), since RSVP reservation could be required in the satellite terminal, but bandwidth allocation still remains a task for NCC.

Mappings in terms of PCs (including QoS parameters) and traffic parameters between IntServ/RSVP service model and DVB-RCS service model are provided below.

The GS is mapped into DVB-RCS PC1 or PC2 according to the requested maximum packet transfer delay, and the data rate has to be specified to the DVB-RCS connection control unit. The PDR to be adopted in DVB-RCS can be computed from IP traffic parameters, i.e. by considering the guaranteed rate (R) and peak rate (p) of the IP flow, which is conveyed by RSVP messages. In particular, the following mapping applies:

- If the DVB-RCS device uses buffers: $\mathrm{PDR}_{\text{DVB-RCS}} = R$.
- Elsewhere: $\mathrm{PDR}_{\text{DVB-RCS}} = \max(R, p)$.

It is worth noting that R is specified in RSVP messages (RSpec field) to obtain bandwidth and delay guarantees, while p is defined in RSVP TSpec to characterize the data source.

CLS is mapped into DVB-RCS PC3–PC5, where traffic fluctuations are allowed. PC1 and PC2 can still be used to accommodate CLS classes when GS service is not performed. Three parameters have to be mapped: PDR, SDR and MBS. These traffic parameters will result from the following RSVP/DVB-RCS mapping formulas:

$$\mathrm{PDR}_{\text{DVB-RCS}} = p$$

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Table II. Mapping of IntServ/RSVP classes to DVB-RCS profile classes.

		DVB-RCS profile classes					
	IP classes	1	2	3	4	5	6
IntServ classes	GS	√	√				
	CLS			√	√	√	
	BE						√

$$\mathrm{SDR}_{\text{DVB-RCS}} = r$$

$$\mathrm{MBS}_{\text{DVB-RCS}} = b$$

where p is the peak data rate, r is the sustainable rate and b is the token bucket size specified in the TSpec parameters for the IP flow.

PC6 does not provide enough capability for CLS as it does not envisage any delay or loss requirement; therefore, it is used only for BE traffic. Table II summarizes the proposed mapping between IntServ/RSVP classes and DVB-RCS PC. It can be noted that, even though all of the profile classes have the capability to carry BE service, the natural PC is the DVB-RCS PC6 which does not envisage any delay or loss bound. As to BE services, there is no traffic description and a default value is typically set by the network operator.

4.1.5. QoS-related mapping between DiffServ and DVB-RCS. The DiffServ IP architecture was proposed in order to introduce a scalable and flexible service differentiation between IP flows. Differently from IntServ, DiffServ has no knowledge of network status (i.e. it is a 'stateless' network architecture) and service guarantees are not assured. Nonetheless, DiffServ architecture results in a very scalable approach to traffic engineering, and, most importantly, it has been recently shown that DiffServ allows network providers to introduce QoS-aware traffic control procedures as well as connection admission control and congestion control procedures [35, 36]. The DiffServ model presently defines three 'behaviours' (PHBs):

- expedited forwarding (EF) PHB [37];
- assured forwarding (AF) PHB group [38];
- the BE level is also considered as a default PHB with no priority at all (BE PHB).

Figure 11 shows a DiffServ-compliant network operation. As a consequence, the RCST terminal is in charge of mapping DiffServ flows belonging to a given PHB, on DVB-RCS streams with proper parameter configuration. The mapping is based on the DiffServ DSCP conveyed by each packet, and it is operated on a per-packed basis. Moreover, the NCC could be also in charge of managing reservation procedures, if any DiffServ-compliant reservation or admission control framework is adopted by the network administrator (see [35] for the gauge and gate reservation with independent probing (GRIP) solution or [39]).

Guidelines to mapping in terms of PCs (including QoS parameters) and traffic parameters between DiffServ service model and DVB-RCS service model are provided below.

EF PHB should be considered the equivalent of GS in IntServ. As a consequence, there are two possible mappings for EF PHB: PC1 and PC2, because of the real time support and

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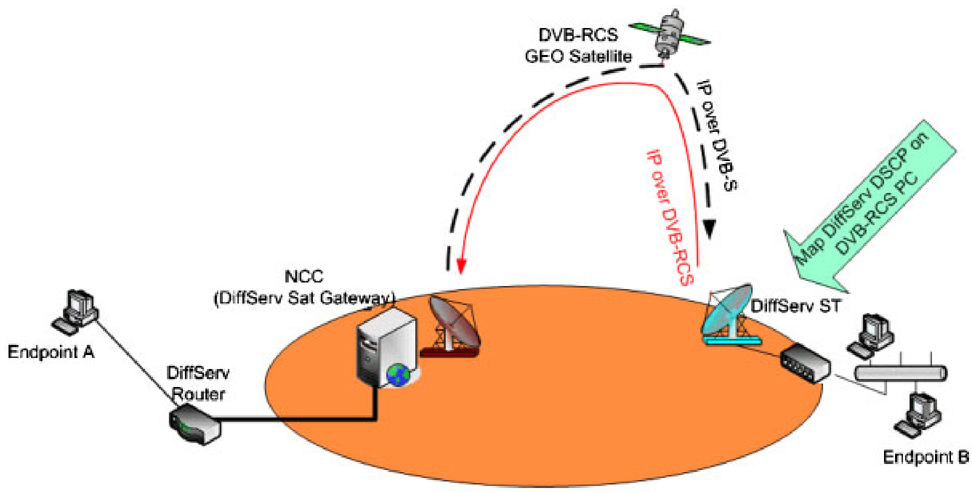

Figure 11. DiffServ-aware DVB-RCS satellite communications.

stringent delay requirements. In DVB-RCS domain, the main difference between PC1 and PC2 is that the first allows to obtain few hundreds of ms for the maximum packet transfer delay, while using the second a delay smaller than 1 s is guaranteed. Since it is not permissible to distinguish between EF streams in DiffServ, the mapping of EF PHB on Profile Class 1 is proposed. This adoption is also suitable, since it leaves more room to AF mapping, which consists of many different QoS levels.

Since AF PHB corresponds to CLS, it is possible to use PC3–PC5, plus the additional PC2 that is not used by EF. This leaves room up to four AF classes, even though up to three additional levels inside each AF class are also required. This implies that up to 12 PC values should be needed instead of the four available values. Hence, two approaches, or a combination of both of them, are envisioned:

- operate a superposition of DSCPs over corresponding PCs;
- reduce the number of DSCPs adopted in the DiffServ domain.

Intra-class differentiation for AF classes is performed at IP level, and no further low level mechanisms are strictly required in order to enforce the specific PHB. Nonetheless, since AF precedence differentiation reflects a condition of differentiated priorities inside the AF macro-flow, it could be useful to support the IP level differentiation by means of L2 precedence mechanisms. Since DVB-RCS does not provide differentiation for packets entering the same queue, the natural solution is to split each AF queue into two or three MAC queues. An AF aggregate could be mapped on a single PC, since internal AF differentiation occurs at network layer. However, a further differentiation at MAC layer is useful, especially for implicit signalling purposes recently proposed in literature [35, 40]. The rules driving this differentiation are defined below.

In Tables III and IV, two configurations are considered, taking into account all AFxy DSCPs (Table III), or just a minimal set of AF DSCPs (Table IV), plus EF and BE DSCPs. Note that in Table III a single AF class is mapped onto two PCs: one for AFx1 (higher performance) and one

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Table III. A possible mapping of DiffServ classes to DVB-RCS profile classes.

DiffServ classes		DVB-RCS profile classes					
Class	Precedence	1	2	3	4	5	6
EF		√					
AF1	1		√				
AF1	2			√			
AF1	3			√			
AF2	1			√			
AF2	2				√		
AF2	3				√		
AF3	1				√		
AF3	2					√	
AF3	3					√	
AF4	1					√	
AF4	2						√
AF4	3						√
BE							√

Table IV. An alternative mapping of DiffServ classes to DVB-RCS profile classes, using a minimal DiffServ set.

DiffServ classes		DVB-RCS profile classes					
Class	Precedence	1	2	3	4	5	6
EF		√					
AF1	Data (1)		√				
AF1	Other (2)			√			
AF2	Data (1)				√		
AF2	Other (2)					√	
BE							√

for both AFx2 and AFx3 (lower performance). Using such a mapping, the network is provided for supporting:

- real-time applications, not jitter-tolerant → EF;
- delay sensitive streams, with low loss requirements → AF1 class;
- slightly delay sensitive streams, with very low loss requirements → AF2 class;
- loosely delay sensitive streams, with low loss requirements → AF3 class;
- very loosely delay sensitive streams, with very low loss requirements → AF4 class;
- best effort → BE class.

A 'terminal interworking and coordination function', of the RCST, determines the IP QoS level of an incoming flow by analysing the information contained in the DSCP field. After processing the DSCP field, the RCST knows the type of service requested by the new flow and it may determine a suitable associated PC.

Table IV only distinguishes between common data, carried by an AF class with precedence 1 (i.e. with AFx1 label), and other packets (including out-of-profile traffic and other semantically differentiated traffic), carried with lower precedence (AFx2 label). In Table IV, an alternative mapping is proposed, and only two AF classes are dealt with:

- very delay sensitive, and loss sensitive streams → AF1 class;
- loosely delay sensitive, very low loss sensitive streams → AF2 class.

Note that DiffServ domains have SLAs and SLSs with adjacent domains, so that the validity of service classes is limited in the scope of a local domain, and service classes translations may be needed. As an example, the case of Diffserv domain with satellite inside, and an adjacent IntServ domain is briefly reported here, and a mapping between IntServ/RSVP and DiffServ is produced. In particular, one can determine the DiffServ–IntServ class correspondences off-line, using the following rules:

- map RSVP messages on EF PHB (signalling);
- determine DVB-RCS PC from IntServ/RSVP-to-DVB-RCS mapping table, obtaining a given PC, say PCx;
- look-up at DiffServ-to-DVB-RCS mapping table and return the nearest DSCP within EF, AF11, AF21, AF31, AF41, and BE; in this way a DiffServ class is detected between EF, AF1, AF2, AF3, AF4, and BE.

As an example of relation between IntServ services and DiffServ classes, the mapping proposed in Table III and a CLS service is considered. Following Table II, there are three possible mappings for CLS: PC3, PC4 or PC5. Suppose that a stream in CLS is not delay sensitive, but it is loss sensitive, so that PC4 is selected. In Table III AF22, AF23 and AF31 DSCPs correspond to PC4, thus AF3 is the less expensive class that is also suitable for carrying data pertaining to that specific stream. In conclusion, data will be carried as AF31 mapped onto PC4, while AF32 and AF33 remain available for advanced operation, such as low priority and low importance packets, out-of-profile packets, or also for implicit signalling operation (if any is provided), and they are mapped on PC5. On the other hand, RSVP signalling, when to be forwarded transparently, should be mapped onto EF PHB and PC1.

4.2. Fusion of digital video broadcasting and mobility management

Mobility management (MM) plays an important role for guaranteeing service continuity in a typical converged network, when an access system is switched while a consumer is moving. One of the fundamental requirements for MM in such a fusion network is the ability to perform seamless handover between dissimilar systems. In ITU-T Recommendation Q.1711 [41], several fundamental requirements and parameters for handover was outlined. The aim of this section is to highlight a possible mapping between the parameters defined by the ITU-T standards and the parameters available in DVB systems so that a network designer can design a system that fuses the different wireless technologies over DVB. In this example, the main focus of the mapping is to ensure that handover between different systems is as seamless as possible by ensuring the management function in charge of handover is capable of retrieving lower layer information for handover. In addition, how the parameters can be obtained using standard simple network management protocol (SNMP) will be described [42].

Figure 12 is the system architecture for protocol conversion consisting of the mapping of the MM parameters defined in ITU standards with the parameters available in DVB systems. For this section, a network consisting of both DVB and WLAN systems is taken as the baseline

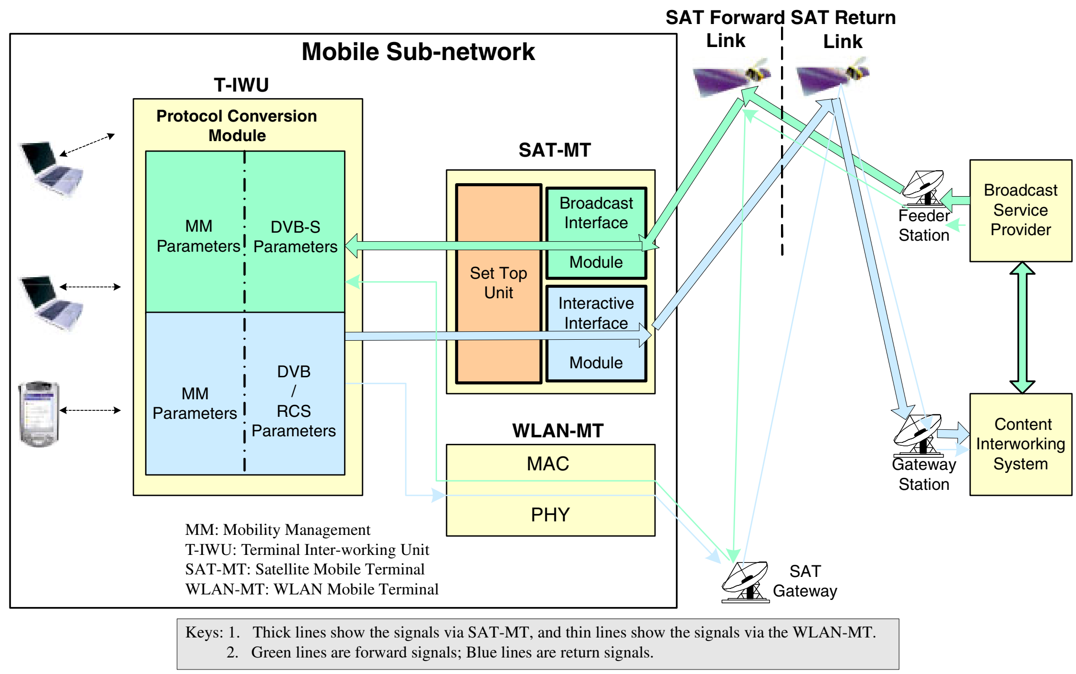

Figure 12. System architecture for protocol conversion [43].

scenario. Two continuous major typologies of service (Internet and broadcast digital TV) can be provided over the converged network. This, for example, could be a sub-network in a high-speed train, where Internet and broadcast digital TV services could be provided to the passengers within the train sub-network whenever and wherever during the train journey [44]. Transmissions are either *via* the satellite mobile terminal (SAT-MT) in the satellite coverage area or *via* the WLAN mobile terminal (WLAN-MT), which acts as an extension segment in areas where the satellite link is unavailable. In Figure 12, two channels are established between the service provider/content interworking system and the mobile sub-network [9]:

- *Forward channel*: The unidirectional broadband broadcast channel including video, audio and data *via* DVB-S. This is established between broadcast service provider and the sub-network. The forward interaction path is from the content interworking system to the sub-network.
- *Return channel*: From the sub-network to the content interworking system *via* the DVB-RCS. This is used to make requests to the service providers/users, to answer questions or to transfer data.

According to the system architecture in Figure 12, the protocol conversion module is inside the terminal inter-working unit (T-IWU), which is the nomadic middleware, and mainly in charge of the MM procedures and other functions including the sub-network self-configuration, security management, routing and QoS management, etc. Two methods of protocol conversion are considered. One is to map the forward direction DVB-S parameters with the MM

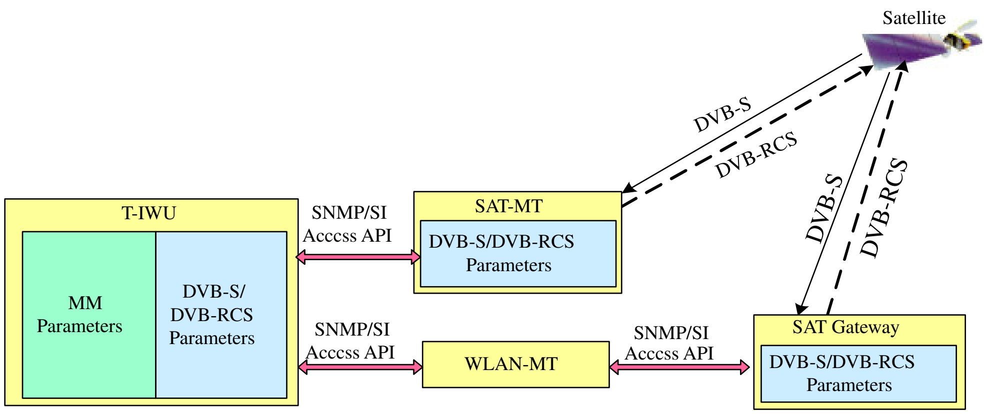

Figure 13. Messages used in protocol conversion.

parameters. The other is to map the return path DVB-RCS parameters with the MM parameters. That is, in a two-way satellite Interactive network, consisting of a forward and return link *via* satellite, some of the MM parameters can be mapped onto forward link signalling [9], for instance, to special transport stream packets (program clock reference (PCR) insertion). For the return link signalling, some of the MM parameters are mapped onto the private management information base (MIB) in the RCST, which stores the configuration parameter values in variables. SNMP commands are used between the NCC and RCST to exchange the configuration parameters to identify the functional capability of the RCST, the transmission characteristics demanded from a particular RCST, and the messages needed for network management [31, 42]. They could also be used between the T-IWU and RCST to obtain the current system configuration parameter values to assist the protocol conversion, that is, an SNMP agent in the RCST responds to commands from an SNMP client in the T-IWU.

As shown in Figure 13, SNMP [42] and service information (SI) access application programming interface (API) specified in [45] are selected as the signalling messages for acquiring the desired DVB-S/DVB-RCS parameters between the T-IWU and the SAT-MT or the SAT Gateway.

MM parameters are crucial for a well-performed location management and handover management. The activation of location update or handover execution function should be performed after careful evaluation and estimation of the MM-related parameters. Varieties of parameters should be considered, including the measurement results of radio channel quality estimation (e.g. received signal strengths, estimated bit error ratios), the QoS assessment information (e.g. packet throughput, delay), updates of location information and/or MT status information, etc. Table V lists several MM parameters related to the required functions such as ‘error’ for radio channel quality estimation, ‘segment status’ for tracing the mobile terminal status (whether terminal is reachable or not), ‘delay’ for QoS estimation. For the baseline scenario in Figure 12, it would be beneficial to map the available network information (e.g. information from DVB-SI/MIB) to the corresponding MM parameters. Table V shows the mapping between some MM parameters defined in ITU standards and the corresponding available DVB parameters in DVB systems.

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Table V. Mapping of MM parameters and DVB parameters.

Parameters of MM defined in [41]	Parameters of DVB-S/DVB-RCS	DVB standards that mapped onto [9, 31]	Definition/description
Segment status	rcstStatusCurrent	ETSI TR 101 790 v1.3.1 (2006-09); F.4 Private Enterprise RCST MIB (rcstLife group)	Defines the current RCST operation status: 'idle' ('1'), 'initialized' ('2'), 'hold' ('3'), 'oamActive' ('4'), 'active' ('5'), 'fault' ('6'), other values shall be reserved for future use
Timestamp	rcstLifeRcstStatus-CurrentTimestamp	ETSI TR 101 790 v1.3.1 (2006-09); F.4 Private Enterprise RCST MIB (rcstLife group)	Timestamp indicating at what time the current operational status has been reached by the RCST
Delay	Propagation_delay	ETSI EN 301 790 v1.3.1 (2005-09); Section 8.5.5.6. PCR Insertion Transport Stream packet	This 32-bit field defines the propagation delay between NCC and satellite as a PCR count. For the forward link it is the delay from NCC to satellite while for the return link it is the delay from satellite to Gateway. RCST may use this information to compute delays
MT Record Data	RcstSysTarge-tEbN0	ETSI TR 101 790 v1.3.1 (2006-09); F.4 Private Enterprise RCST MIB (idu subgroup)	This value describes the wanted E_b/N_0 value that enables operation of the return link with the required error performance
	RcstSysEbN0Range	ETSI TR 101 790 v1.3.1 (2006-09); F.4 Private Enterprise RCST MIB (idu subgroup)	This value describes the possible range of E_b/N_0 variation that can be compensated by the system
Error	ifInErrors	ETSI TR 101 790 v1.3.1 (2006-09); F.5 MIB-II (interfaces group)	The number of inbound packets discarded because they contain errors
	ifOutErrors	ETSI TR 101 790 v1.3.1 (2006-09); F.5 MIB-II (interfaces group)	The number of outbound packets discarded because of errors

5. RESEARCH DIRECTIONS

A future converged network aims at providing seamless services for all types of communication services regardless of network or handset type. This is expected to be achieved through IP-based network comprised of different access platforms. The evolution of mobile communication to an all-IP network to enable service operated in various networks will become an important issue for future broadband mobile communications. IP-based mobility management is required to guarantee service continuity even when the access network is switched while the consumer is moving. For instance, fast handover strategies are required to conquer the limitation of mobility function to assist in seamless and continuous data service when a consumer is on the move at high speed. An adaptive and smart handover control mechanism is necessary to act as a

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Table VI. Challenges in a fusion network.

OSI layers	Research challenges in the different layers
Application layer	Flexible service creation User-based networking User-perceived QoS Adaptive applications/services Security/authentication, authorisation and accounting (AAA)
Session layer	Service discovery User profile management End-to-end QoS negotiation
Network layer	Mobility management Network layer QoS support Overall IP-based network architecture

common framework to make seamless handovers across the different access technologies by selecting the best handover performance depending on the current network availability and user/application preferences. Mobile IP defined by the IETF is the basic solution to provide mobility support, independent of access network types and transparent to all the applications. However, because the mobile IP technology has until now mainly focused on providing mobility to the wired Internet, it has limitation to support frequent fast handover in the wireless Internet environment. Research development on fast mobile IP handover algorithms to minimize the processing delay of mobile IP remains as an open issue for the next-generation fusion network [1]. An example is the recently approved IETF RFC, 'Fast Handovers for Mobile IPv6', by the IETF mipshop (MIPv6 Signalling and Handoff Optimization) work group [46]. Moreover, because of the weaknesses of IPv4 (limited address space), the implementation of IPv6 movement in the next-generation fusion network is another important issue. Several research challenges in the different layers are summarized in Table VI.

In terms of development of DVB systems, areas of current research include the adoption of adaptive coding and modulation as a part of the DVB-S/DVB-RCS specifications. The advanced physical layer design is expected to offer significant benefits to the efficiency of transmission, but also introduces considerable complexity and many design choices when used to construct IP-based networks.

While SATLABs seek to promote interoperability, testing and application of DVB-RCS, the DVB-RCS working group itself continues to develop the base standard. Important goals will be the introduction of QoS support, advancing support for IP multicast, provision of link/system security and the evolution of the system to reduce system costs and support a range of IP-based services.

The ETSI/BSM WG seeks to complement the work in DVB-RCS and other satellite networking technologies. This WG takes an IP-centric view of the satellite system, defining a SI-SAP [47] that provides the protocol interface between the network layer (IP network) and the satellite network. Above the interface, IP-based protocols provide end-to-end networking functions, whereas below the interface, IP packets are mapped to the capabilities of the individual satellite services. The work will seek to develop protocol methods to allow the next generation of satellite systems to support seamless provision of security, quality of service, address resolution and multicast support. This work is now proceeding for IPv4, and it is anticipated that this will be expanded to IPv6 in the future.

Within the IETF ipdvb WG, the work will focus on defining mechanisms and protocols to allow the satellite network to function as a part of the global Internet infrastructure. Following specifications of the framework [14] and the definition of the ULE protocol [11], the WG is currently focused on the topics of address management, and provision of extensions for new protocol elements to enhance the ULE specification. In terms of the ETSI/BSM architecture, this new work focuses on work above the SI-SAP.

The convergence and fusion of DVB-S systems offers the potential to develop and deliver a vast array of new services and applications. The technological alliance formed by a network comprising satellite broadcasting technology with standard IP protocols will enable the smooth integration of satellite services with mobile and Internet technologies.

APPENDIX: ACRONYMS AND ABBREVIATIONS

3GPP	third generation partnership project
4G	fourth generation
AAA	authentication, authorization and accounting
AAL	ATM adaptation layer
AAL5	ATM adaptation layer 5
ADSL	asymmetric digital subscriber line
AF	assured forwarding
AHG	*Ad hoc* Group
API	application programming interface
ATSC	Advanced Television Standard Committee
AVBDC	absolute volume-based dynamic capacity
BE	best effort
BSM	broadband satellite multimedia
CLS	controlled load service
CRA	continuous rate assignment
DiffServ	differentiated services
DAB	digital audio broadcasting
DVB	digital video broadcasting
DVB-H	digital video broadcasting-handheld
DVB-RCS	DVB return channel by satellite
DVB-S	digital video broadcasting *via* satellite
DVB-S2	second-generation DVB system for broadband satellite services
DVB-T	digital video broadcasting-terrestrial
E2R	end-to-end reconfiguration
EF	expected forwarding
ETSI	European Telecommunications Standard Institute
FCA	free capacity assignment
GGSN	gateway GPRS support node
GMC	generalized multicarrier
GS	guaranteed service

HP	high priority
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	IP multimedia subsystem
IntServ	integrated services
ipdvb	IP over DVB
IPsec	Internet protocol security
IrDA	infrared data association
LLC	logical link control
MAC	medium access control
MBMS	multimedia broadcast-multicast service
MBS	maximum burst size
MF-TDMA	multiple frequency-time division multiple access
MIB	management information base
MIMO	multiple-input multiple-output
mipshop	MIPv6 signalling and handoff optimization
MM	mobility management
MPE	multi-protocol encapsulation
MPEG	moving pictures expert group
NCC	network control centre
p	peak rate
PC	profile class
PCR	program clock reference
PDR	peak data rate
PHB	per hop behaviour
PID	packet ID
PLR	packet loss ratio
OMG	object management group
QoS	quality of service
R	guaranteed rate
RBDC	rate-based dynamic capacity
RCST	return channel satellite terminal
RSVP	resource reservation protocol
SAE	system architecture evolution
SatNEx	Satellite Communications Network of Excellence
SDP	session description protocol
SDR	sustainable data rate
SI	service information
SIP	session initiation protocol
SI-SAP	satellite independent-service access point
SNAP	sub-network access protocol
SNMP	simple network management protocol
SOHO	small office-home office
T-IWU	terminal inter-working unit
TS	transform stream
ULE	unidirectional lightweight encapsulation

UMA	unlicensed mobile access
UMTS	universal mobile telecommunications system
VBDC	volume-based dynamic capacity
VoIP	voice over IP
WG	working group
WLAN	wireless local area network
WLAN-MT	WLAN mobile terminal
WMAN	wireless metropolitan area network
WPAN	wireless personal area network
WWRF	wireless world research forum

ACKNOWLEDGEMENTS

This work has been performed by members of the Satellite Communications Network of Excellence (SatNEx) project, which is supported by the European Commission under the Sixth Framework Information Society Technologies Programme.

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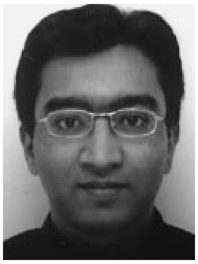

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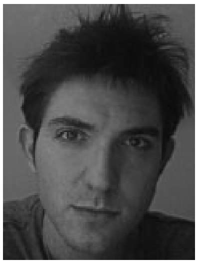
DOI: 10.1002/sat



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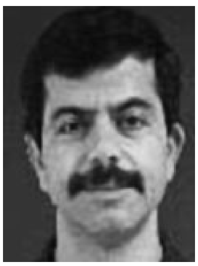

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DOI: 10.1002/sat