Fusion of Digital Television, Broadband Internet and Mobile Communications

Part II of 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. This part focuses on the current and future operational scenarios for DVB-S system. Scenario based review of current state-of-the-art technologies consisting of integration of broadband Internet and mobile communication and integration of broadband Internet and DVB are given. The future operational scenarios emphasises the fusion of DVB systems with various access technologies, terminal, services and network. It also takes into consideration mobility management (MM) and standard quality of service (QoS) mechanisms issues, such as integrated services (IntServ) and differentiated services (DiffServ). Several research directions for providing seamless services regardless of network, access technology, and terminal in the fusion network are also highlighted in this paper.

KEY WORDS: DVB, DVB-S, DVB-RCS, DVB-S.2, Mobility Management, Quality of Service, Fusion/Convergence of services.

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1 Introduction

DVB was initially designed for the purpose of video broadcasting services. However, the growth of the Internet and the world wide web (WWW) is expected to drive the development of DVB networks to support the transport and delivery of IP-based applications and services, in addition to the delivery of video broadcasting services. This will indirectly lead towards the integration of broadband Internet and digital television, as shown in Figure 1. At the same time, mobile communication is also currently undergoing a state of enormous transition. Many of the cellular operators are developing networks to support the packet switched data services. A strong trend in the integration of broadband Internet and mobile communication is known as “IP goes mobile and mobile gets IP”, which is a competitive way of developing toward the broadband mobile multimedia packet service [ITU04]. Furthermore, the rapid growth of multimedia communication over the Internet and the emergence of varied, powerful mobile technologies and terminals is driving the digital wireless communication system to the third generation (3G) mobile system and beyond, where fusion between digital television and mobile communications, and fusion among digital television, mobile communication and broadband Internet could be beneficial. This is because various advanced services could be delivered to the customers via versatile mobile terminals and technologies in global areas crossing personal, home, train, enterprise spaces, etc, within 3G and beyond 3G (B3G) network.

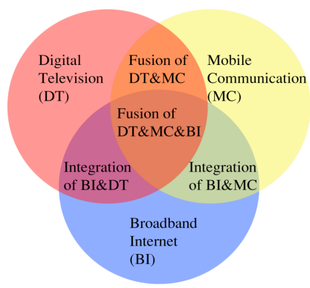


Figure 1: Fusion in Digital Television, Broadband Internet and Mobile Communications

This paper focuses on a survey of current and future operational scenarios in the fusion of digital television, broadband Internet, and mobile communication. A scenario based review of current state-of-the-art technologies, which comprised of the integration of broadband Internet and digital television, and integration of broadband Internet and mobile communication are addressed in section 2. Section 3 describes the development of future operational scenario of DVB system, emphasising first, the fusion of access technologies, mobile and wireless access technology and service, network and terminal fusion, secondly, mobility management in a fusion network to guarantee service continuity, and thirdly the fusion of DVB with standard QoS mechanisms, such as IntServ and DiffServ. Finally, future research directions in this field will be discussed before concluding the paper.

2 SCENARIO BASED REVIEW OF CURRENT STATE-OF-THE-ART TECHNOLOGIES

2.1 Integration of Broadband Internet and Mobile Communications

2.2 Integration of Broadband Internet and Digital Video Broadcasting

Today's network devices rely on heterogeneous data-link (L2, i.e. the Layer 2 of the OSI model) technologies over definitely different physical infrastructures (L1, i.e. the OSI Layer 1) . In particular, 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 (located at L3) and underlying protocols. Well known solutions are the AAL5 (ATM Adaptation Layer 5) for ATM networks or LLC (Logical Link Control) for the IEEE 802.1 MAC family, which are commonly adopted in terrestrial networks. AAL mechanisms have been also deployed over satellite systems, and another example of adaptation layer is the MPE (Multi-Protocol Encapsulation) defined by ESTI for the encapsulation of ethernet frames and/or IP datagrams into MPEG-2 Transport Streams (see [MON05] for a broader discussion). More in general, each IP data flow has to be converted into a technology-dependent stream and vice versa. This conversion requires operations like processing of signalling and implies a reduction of the throughput of the overall system. In fact, the conversion introduces additional overhead in terms of both elaboration time (CPU cycles) and protocols (mainly due to the addition of new headers in each data segment). Each datagram and each frame has to be parsed by the network device located in the satellite payload or in the terrestrial hardware due to possible fragmentation, packing and tunnelling/encapsulation protocols that can be adopted. These kind of management operation has to be tailored for each specific data-link layer that is implemented in the (satellite) device.

Moreover, 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 prioritisation mechanisms such as RSVP (Resource Reservation Protocol) [BRA97] or DiffServ PHBs (Per Hop Behaviours) [NIC98, BLA98]. Of course, the adaptation-layer between L3 and L2 should strictly or loosely reflect the behaviour of the traffic engineering approach adopted at L3. For instance, if a specific L2 solution does not permit any bandwidth reservation on a hop-by-hop basis, then reservation protocols like RSVP, ST and ST2 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, where L3 and L2 protocols/parameters can be tuned in order to match with each other.

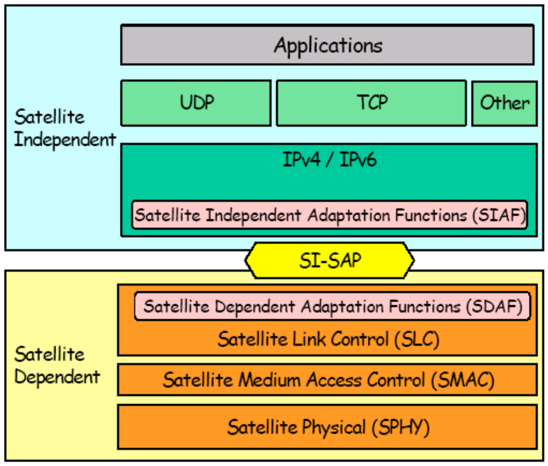


Figure 2: The ETSI-BSM protocol stack

According to the ETSI-BSM QoS architecture for Broadband Satellite Multimedia [ET984, ET985], 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 opaque for the IP end-user.

The SI-SAP proposed in ETSI-BSM allows for translation of data format from IP to satellite-dependent packet types, and vice versa. In case of widely diffused ATM-based satellites, the SI-SAP is the interface that converts IP datagrams into bit streams to be parsed by an ATM Adaptation Layer (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 operates as switches between IP queues and ATM queues.

As a concrete example, assuming the case of DVB-RCS satellites, IP flows can be converted into ATM cell flows or encapsulated into MPEG streams [ETS97, ETS02], while different schemes can be adopted as to the resource allocation mechanism over the satellite link, or as to the prioritisation 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 these days, 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, since they requires an expense of a few hundreds of euros per month, with a performance comparable with common ADSL subscriptions. Mostly common products are DVB-S-based, thus requiring a terrestrial return channel (i.e. a modem transmitting over telephony lines, cables or xDSL, where available). 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 fares are more expensive then the one of DVB-S and DVB-S2.

Up to date, DVB-S, DVB-S2 and DVB-RCS satellite systems support most of relevant TCP/IP protocols, such as TCP, UDP, IP, ICMP, RIP and IGMP, and also provide special QoS features like TCP accelerators (enhancing TCP performance over satellite path), and bandwidth on-demand management. It is worth noting that commercial solutions adopt proprietary applications and user-interfaces in order to provide special services like VoIP (Voice over IP) or Video on-demand, and in order to furnish broadband download services, proprietary databases, proxy servers, 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.

Moreover, different services require different QoS provisioning methods and, in turn, separate QoS classes. For example, 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 spit into “jitter-tolerant” and “jitter-sensitive” subclasses. However, the four classes before are the ones proposed by 3GPP [EUQ04] for the deployment of IP services in 3G networks (which also includes satellite-based radio access networks for mobile users). 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 quality of service 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 as in the example before. For instance, traffic flows can be separated by means of well known IP methods, based on 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.

Thus, in the following subsections, we give an overview of the QoS-related parameters of both the IP IntServ/RSVP model and DiffServ model, that can be exploited both in terrestrial and satellite networks. We will shortly review their models and parameters by considering the underlying network-to-data-link interface which is responsible for any general-purpose QoS-aware applications; we will also furnish a presentation of the DVB-RCS features that enable QoS-aware transport of IP data. An example of QoS-oriented cross-layer interoperation (L2-L3) will be presented in section 3.3.1.

2.2.1 IntServ Services (L3)

In a 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 [BRA94]. Each flow is separately managed, and the network approach is "stateful", which means that each network node is aware of the needs of each session and a resource reservation is performed for each session. Actually, resources can be reserved strictly or loosely in accordance with the degree of QoS to be provided. Thus, the level of QoS provided by these enhanced QoS classes is programmable on a per-flow basis according to the service requested by the user.

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 GS (Guaranteed Service) and CLS (Controlled Load Service). In parallel with these two services the default BE (Best Effort) 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 [WRO97].

The QoS provided by a GS implies: assured level of bandwidth (guaranteed throughput), mathematically bounded end-to-end delay (guaranteed maximum delay) and no queuing losses for "conforming" packets. It is worth noting that sources and network agree on a set of transmission parameters before the beginning of the data exchange, and when a source overrides that agreement (e.g. by sending data at a rate higher then the maximum guaranteed rate), a fraction of the traffic is "non-conforming" and it has to be forwarded by a node only if spare resources are available at that network node: non-conforming traffic is treated as legacy best effort (BE) traffic. The applications requiring a GS specify both the traffic characteristics (TSpec, containing the peak data rata, the allowed burst size, the average data rate of the source and other parameters) and reservation characteristics (RSpec, containing basically the reservation bandwidth) in the RSVP protocol exchange.

The CLS is intended to support a broad class of applications which have been developed for use in today's Internet but are highly sensitive to overload conditions. Important members of this service class are the adaptive real time applications with loose delay requirements. The QoS offered by a CLS is similar to those achievable by a BE service in an unloaded network. The CLS does not accept or make use of specific target values for control parameters such as delay or loss. Applications which require a CLS specify only the traffic characteristics (TSpec) while the reservation characteristics

(RSpec) are not required. Again, non-conforming traffic is treated as BE.

Figure 3 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 stressed in the figure. As a consequence of the 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 Network Control Center (NCC) is the gateway to the Internet, and the core of the satellite network, as concerns management issues. The NCC is in charge of managing reservation procedures triggered by RSVP message exchange. To this aim, 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.

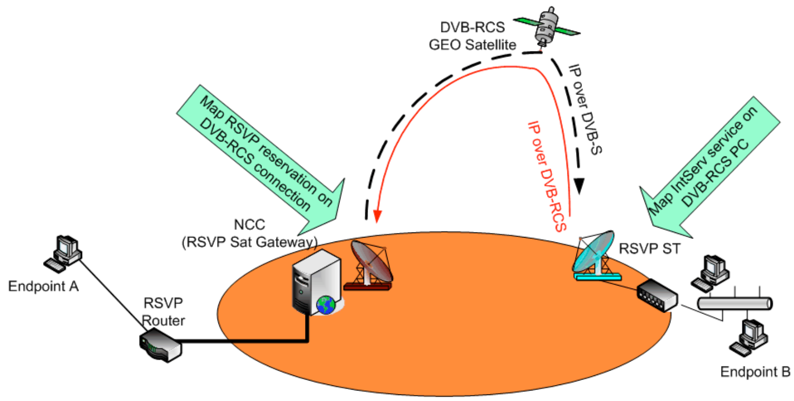


Figure 3: IntServ-aware DVB-RCS satellite communications

2.2.2 *DiffServ Services (L3)*

The DiffServ IP architecture was proposed in order to introduce a scalable and flexible service differentiation between IP flows. DiffServ IP networks operate a flow aggregation at domain edges. The resulting macro-flows (or “traffic aggregates”) receive separate treatment inside the DiffServ domain. Each DiffServ node is provided a set of different “behaviours” (PHB) to operate in correspondence with different traffic aggregates, thus obtaining a service differentiation in terms of bandwidth, delay performance, latency and packet loss. 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 scalar 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 [BIA01, BIA02].

The DiffServ model presently defines three PHBs. The class selector PHB replaces the IP precedence field of the former TOS (Type of Service) byte in the legacy IP packet header. DiffServ additionally offers two relative forwarding priorities:

- the EF (Expedited Forwarding) PHB [JAC99] guarantees that packets will have a well-defined minimum departure rate which, if not exceeded by network sources, ensures that the associated queues are short or empty. EF is intended to support services that offer tightly bounded loss, delay and delay jitter;

- the AF (Assured Forwarding) PHB group [HEI99] offers different levels of forwarding assurances for packets belonging to an aggregated flow. Each AF group is independently allocated forwarding resources. Packets are marked with one of three drop precedences, the ones with highest drop precedence are dropped with greater probability than those marked with the lowest drop precedence. DSCPs are recommended for four independent AF groups, although a DiffServ domain can have more or fewer AF groups.

Eventually, the BE level is also considered as a default PHB with no priority at all (BE PHB).

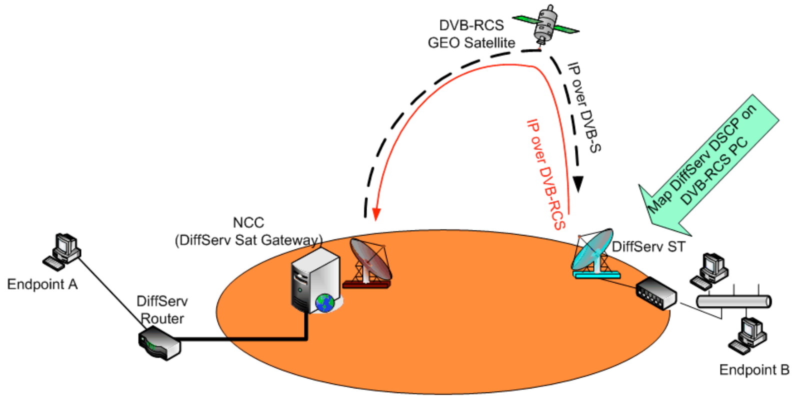


Figure 4: DiffServ-aware DVB-RCS satellite communications

Figure 4 shows a DiffServ-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 in upstream). 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 [BIA01] for the GRIP solution or [SAR02]).

2.2.3 DVB-RCS Services (L2)

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 are managed by the NCC. During the connection lifetime, bandwidth is requested by the RCST and assigned by the NCC through five capacity categories:

- Continuous Rate Assignment (CRA): it is a fixed guaranteed rate, negotiated at the beginning of the DVB-RCS connection between the Satellite Terminals and the NCC. CRA should be used for traffic which requires a fixed guaranteed rate, with minimum delay and minimum delay jitter.

- Rate Based Dynamic Capacity (RBDC): it is a dynamically requested rate, corresponding to the full rate currently being requested. RBDC should be used for variable rate traffic which can tolerate delay. CRA and RBDC can be used in combination, with CRA providing a fixed minimum capacity per frame and RBDC giving an additional dynamic component.

- Volume Based Dynamic Capacity (VBDC): it is volume capacity which is requested dynamically by the Satellite Terminal. VBDC capacity requests are cumulative. VBDC should be used only for traffic that can tolerate delay jitter, since VBDC provides a low priority capacity extension above the guaranteed limit in the RBDC or CRA categories.
- Absolute Volume Based Dynamic Capacity (AVBDC): it is like VBDC, but it is expressed in absolute terms.
- Free Capacity Assignment (FCA): it provides the automatic assignment of unused bandwidth (if any), and it is intended as extra capacity for traffic that tolerates delay jitter.

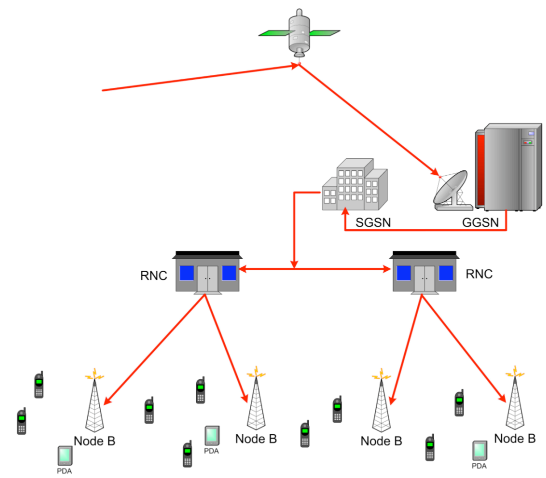
Each DVB-RCS connection is provided with one of these mechanisms, or with a combination of two or more of them, in order to combine a certain amount of fixed resources with a variable quantity of shared resources, whose availability is not completely assured, and it can be negotiated on demand.

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 bearing services. Similarly to IP classes, these L2 bearers also exploit the availability of i) separate queues and ii) priority-based scheduling between queues.

3 Future Operational Scenarios

3.1 Fusion of Digital Video Broadcasting and Mobile Communications

The increasing need for broadband services, especially broadcasting services, led to the development of standards, such as DVB, in order to enable the wide spread use of these systems and services. On the other hand, Mobile Communications, and cellular networks in particular, met a tremendous growth and commercial success. Even though the penetration of 3G mobile phones and services is below expectations, users will eventually switch to third generation technology. 3G cellular phones will have a lot of capabilities and shall support broadband services, such as video streaming. A fusion between Digital Video Broadcasting and Mobile Communications could be beneficial. DVB-S could be used for Broadcast/Multicast wideband data delivery via the Gateway GPRS support node (GGSN) of a universal mobile telecommunications system (UMTS) cellular network, which will further distribute the information to mobile users.



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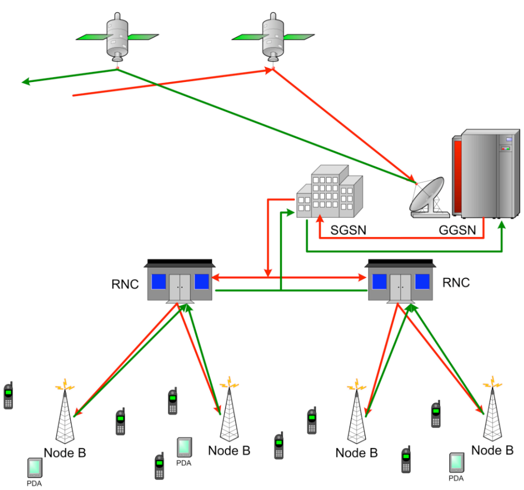
The UMTS network could be also used for the return path, given that the GGSN is equipped with a DVB-RCS interface.



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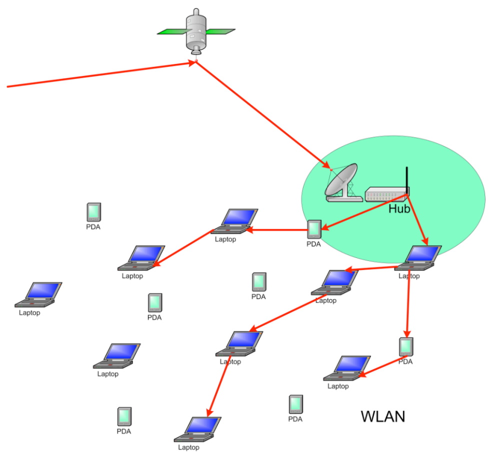
Wireless local area networks (WLANs) can also exploit DVB. For example, all hotspots in an airport could be connected to a central node, equipped with a DVB interface for the delivery of broadband services to mobile users. Moreover, WLAN standards nowadays support communication speeds approximately equal, or even higher, than DVB, so WLAN users could take advantage of all the available bandwidth and benefits the DVB offers. This could be also extended to multihop WLANs, or ad hoc networks, however, these networks have less bandwidth available, due to routing problems that have to be solved.



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3.2 Fusion of Digital Video Broadcasting, Mobile Communications and Broadband Internet

Historically networks and service platforms have evolved independently. Broadcast networks deliver "one-to-many" audio/video/multimedia content to collective consumers. Conversely, telecommunications deal with wireless and wired "one-to-one" interactive communications between individuals. Internet networks encountering the increment of consumer demands in transmission speed, QoS and traffic load have entered the broadband Internet era. Expansion of bandwidth in mobile communication network and the development of IT technology such as the digitisation of source content and the increment of transmission formats and protocols have removed many technical barriers that prevent the data transmission across the independent networks and accelerate the fusion of DVB, and mobile communication [ITU04].

In addition, following the relatively successful second generation (2G) and 2.5G periods, worldwide operators have started to deploy and research in 3G and B3G systems. Looking beyond 3G, the future mobile networks will be the provision of broadband access, widely available multimedia, seamless roaming, and utilisation of the most appropriate connectivity technology. As shown in Figure 8, in B3G systems, significant changes are the paradigm shifts towards Internet protocol (IP), where enhanced IPv6 networking acts as the catalyst to integrate wired/wireless systems and applications into a seamless broadband mobile Internet. In other words, based on IP technology, B3G systems are able to offer customers seamless access to personalised data and services at a high speed over diverse radio access technologies, on a wide range of terminal types. In addition to current technology such as global system for mobile communications (GSM), enhanced data for global evolution (EDGE), wideband code division multiple access (W-CDMA), wireless fidelity (WiFi), future technologies may include, high performance radio LAN 2 (HiperLAN2), worldwide interoperability for microwave access, also known as 802.16 (WiMAX) and DVB (DVB-S, second-generation DVB system for broadband satellite services (DVB-S.2), DVB-RCS, etc). Therefore, the future network is towards a converged world, where fusion among digital broadcasting network, mobile communication network and broadband Internet is a new trend.

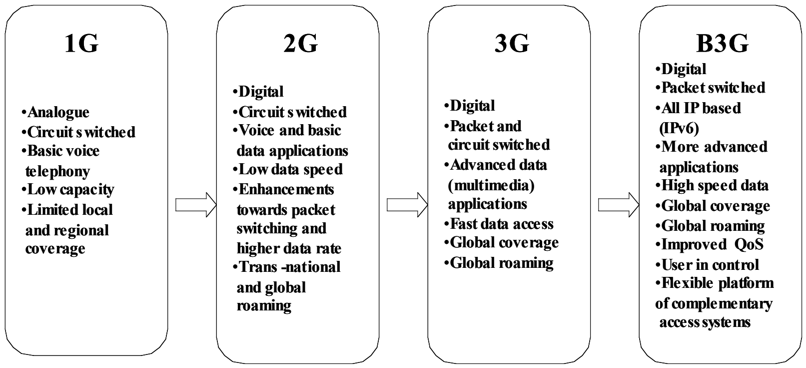

Figure 8: Paradigm Shift from First Generation (1G) towards B3G

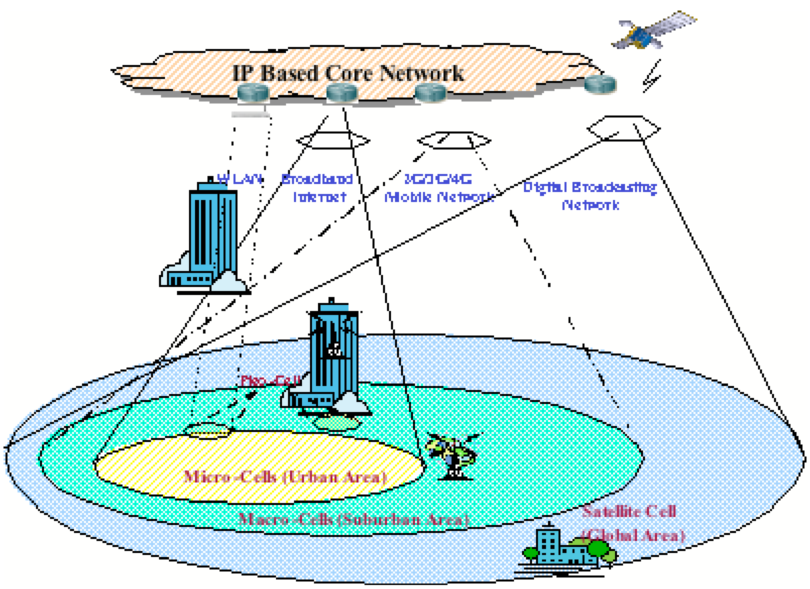

Figure 9: Fusion Network Architecture

Fusion is the key concept in development of the next-generation heterogeneous network and brings out many benefits. The next-generation heterogeneous network becomes more economical, because the existing network infrastructure can be upgrade to support other broadband services and thereby substitute a few of different network offering the same services. A consumer is convenient to connect through a variety of platforms and devices, anywhere, anytime, at a wide range of speed within the fusion environment. However, the fusion of DVB, mobile communication and broadband Internet also brings out several technical challenges together with some market and regulatory problems [FP604]. Technical fusion perspectives are focused in the following section.

3.2.1 Access Technology Fusion

Fusion trend of access technology includes not only cellular network but also emerging systems, such as WLAN, DVB, and the Internet infrastructure. Various access systems should coexist in order to provide integrated and seamless ubiquitous services via a common IP-based core network. It is necessary for a mobile terminal (MT) to employ various points of attachment to maintain connectivity to the corresponding nodes all the time. As shown in Figure 9, the heterogeneous access systems could be organised in a hieratical structure according to their application areas, radio environments, and cell range. Seamless intersystem roaming across heterogeneous networks will be one of the main features. Macro-mobility and micro-mobility should guarantee the continuous services while roaming between the same or different systems. Mobility management performed by handover and session continuation should be particularly considered as well.

Fixed Terrestrial Access Technologies

Digital subscriber line (DSL) is a wire-line transmission technology that converts existing copper telephone lines into two-way high-speed data conduits. The data transmission speeds do not decrease during periods of heavy local Internet use, but are affected by the distance between the end consumer and the phone company central office. Different types of DSL transmission technologies can be used to provide broadband Internet access including asymmetric DSL (ADSL) [DSL01a], symmetrical digital subscriber line (SDSL) [DSL02], symmetric high-speed digital subscriber Line (SHDSL) [LIN00], and very high-data-rate digital subscriber line (VDSL) [DSL01b].

Cable network that currently provides television service to consumers is being modified to provide broadband access. Cable access network offers shared bandwidth or speed among consumers on the same cable system. Unlike the xDSL network, speed of the cable network is asymmetric and varies depending on the number of consumers on the network.

Fibre to the home (FTTH) and fibre to the business (FTTB) is another broadband technology that provides long distance voice, video and data traffic. It has a tremendous data capacity with rates in excess of 1000 Mbps. New equipment and techniques are making it feasible to add fibre to home at lower cost [FTT03].

Power line broadband (PLB) is the delivery of data communication over the existing electric power distribution network. It provides high-speed Internet access with the speeds, which are comparable to the speeds of xDSL and cable. PLB use the low voltage (230/400V) main network for data transmission purposes. The two application fields for the PLC are the customer premises or home networks and access networks.

Satellite Access Technologies

Satellites are used to transmit telephone, television and data signals originated by common carriers (broadcasters and distributors of broadcast), and cable TV programme material. High-speed Internet access via satellite provides consumers another wireless alternative and is ideal for business and consumers who can not subscribe to traditional high-speed Internet access methods, such as people residing in rural and remote areas.

Inmarsat broadband global area network (BGAN) system has been specified to support point to point telecommunication services on portable and semi fixed land mobile platforms at the bit rates of 216 kbps to 432 kbps in downlink, and 72 kbps to 432 kbps in uplink, depending on type of terminal. BGAN service offers circuit and packet switched data services as well as voice services using the Inmarsat 4 series satellites. However, evolution of BGAN air-interface and platform is under-going for the extension of the platform and service baseline to the full range of mobile platforms (maritime, aeronautical, land-vehicular and omni-directional); and in the mobile satellite services (MSS) domain, evolution of BGAN service is being developed towards the support of efficient multicast. In addition, the regional broadband global area network (RBGAN) has been specified as a packet data network to provide Internet access direct to laptop sized portable terminals with a footprint stretching across 99 countries [INM02].

Mobile and Wireless Access Technologies

Due to the mobility limitation of the wired broadband technology, different wireless access technologies are designed to support the relative lower data rate, but mobility in wide areas. 3G wireless systems have been designed from the outset to offer a significantly higher data rate than current 2G mobile systems. The International telecommunication union (ITU) requires that 3G systems support data service at minimum transmission rates of 144 kbps in mobile (outdoor) and 2 Mbps in fixed (indoor) environments. Despite ITU 3G standard, there are multiple 3G standards, such as UMTS, i.e. W-CDMA, code division multiple access 2000 (CDMA 2000). Table 1 summarises the 2G/3G cellular wireless data transport terminology.

Transport Technology	**Description**	**Typical Use/Data Transmission Speed**	**Pros/Cons**
TDMA	Time Division Multiple Access (TDMA) is 2G technology.	Voice and data up to 9.6 kbps.	Low battery and less power control needed, but the transmission is one-way at low speed.
GSM	Global System for Mobile Communications is a 2G circuit switched digital technology.	Voice and data.	Popular around the global.
GPRS	General Packet Radio Service is a 2.5G network that supports data packets. It represents the first implementation of packet switching within GSM.	Data up to 115 kbps; the AT&T Wireless GPRS network will transmit data at 40 kbps to 60 kbps.	GPRS is an essential precursor for 3G as it introduces the packet switched core required for UMTS
EDGE	Enhanced Data rates for GSM Evolution. Builds on GPRS air interface and networks. Also known as enhanced GPRS (E-GPRS)	Phase I supports data up to 384 kbps.	Evolutionary path to 3G services for GSM and TDMA operators.
CDMA	CDMA is a 2G technology.		The fast-growing technology has more capacity than TDMA.
W-CDMA	W-CDMA (also known as UMTS) is 3G technology.	It offers up to 2 Mbps for local area access or 384 kbps for wide area access, and up	Good for roaming globally.

		to 10 Mbps in the coming release.	
CDMA 2000 1xRTT	A 3G technology based on the CDMA platform, 1xRTT is the first phase of CDMA 2000. (1x refers to the number of 1.25 MHz channels; RTT stands for radio transmission technology.)	Voice and data up to 144 kbps.	Migration from TDMA is simpler with CDMA 2000 than W-CDMA, and that spectrum use is more efficient.
CDMA 2000 1xEV-DO	CDMA 2000 1xEV-DO (evolution data optimised) delivers data on a separate channel.	Data up to 2.4 Mbps.	(see CDMA 2000 1xRTT above)
CDMA 2000 1xEV-DV	Integrates voice and data on the same channel.	Voice and data up to 3.09 Mbps.	(see CDMA 2000 1xRTT above)

Table 1: 2G/3G Cellular Wireless Data Transport Terminology

Considering the increasing popularity of wireless information terminals, WLAN enables easy and high-speed Internet access through a laptop or a personal digital assistant (PDA) in relative small areas with limited mobility. There are two dominant WLAN standards: IEEE 802.11 and HiperLAN. The original 802.11 standard was specified in 1997 for operation in the 2.4 GHz unlicensed industrial, scientific and medical (ISM) band with data rates up to 2 Mbps. Since then 802.11 has undergone enhancements that data rates up to 54 Mbps, better support for QoS, improved security are achieved. Table 2 summarised some existing and emerging wireless technologies.

Network	Standard	Radio basic rate	Frequency band	Mobility
WLAN	IEEE 802.11b	1, 2, 5.5, 11 Mb/s	ISM 2.4 GHz	Low
	IEEE 802.11a	Up to 54 Mb/s	ISM/UNI 5 GHz	Low
	IEEE 802.11g	Up to 54 Mb/s	ISM 2.4 GHz	Low
Bluetooth	IEEE 802.15.1	1 Mb/s	ISM 2.4 GHz	Low
WMAN (Wireless Metropolitan Area Network)	IEEE 802.16	134 Mb/s	10-66 GHz	N/A
	IEEE 802.16a	70 Mb/s	2-11 GHz	N/A
UWB (ultra wideband)	IEEE802.15.3a (?) or de facto	Potentially up to 400 Mb/s	3.1-10.6 GHz (Federal Communications Commission (FCC))	N/A
Next-generation WLANs		Up to 1 Gb/s (indoor), 150-250 Mb/s (outdoor)	_	Low

Table 2: Various Existing and Emerging Wireless Technologies [Mäh04]

3.2.2 Terminal Fusion

Terminal fusion implies the convergence of consumer devices such as the fixed phones, smart phones (mobile phones with imaging, video, music, push-to-talk, and business applications), music devices, game decks, PDA, television and Personal Computer. Terminal fusion is based on end-user requirements and the service experience. Traditional terminals maybe limited by the functionality and the air interface, however a fusion terminal is able to support two or more aligned tasks with multiple air interfaces and transmission schemes enabled. A mobile phone with digital camera and a smart phone supporting email services are good examples. The complement of multi-modal devices with each other results in a trend to synchronise the stored personal information such as address books, messages, and agendas.

3.2.3 Service Fusion

Service fusion implies that the same content can be transmitted through different types of technical platforms due to the platform synergy driven by the digitalisation of the content. This is because the same content can be transmitted across different networks in a digital world. Synergy of the platforms achieves the fusion of services among the broadcasting services, mobile content services and Internet based services.

From the service provider's point of view, the fusion of mobile communication and broadcasting service implies the mobile communication broadcasting service on the one hand, which is provided by the mobile communication service providers over the mobile communication network. For instance, online video of news provided by the mobile service can be the same content as delivered via broadcasting network. On the other hand, the fusion of mobile communication and broadcasting service implies the interactive data broadcasting service, which is provide by the broadcast service providers using return channel in mobile communication networks [ITU04]. DVB-RCS is one of the significant broadcast technologies supporting interactive IP services and leads to an evolution from broadcasting to multicasting or point-to-multipoint [ETS97a].

In addition, DVB 2.0 plays an important role in digital convergence of building a content environment that combines the stability and interoperability of the worldwide broadcast with the vigour, multiplicity and innovation of servic Internet. Ongoing activities under DVB 2.0 are intent to build bridges to the worl and telecommunications as shown in Figure 10 [DVB03]. In the near future, it is expected that advanced services including digital TV, broadband Internet, voice call and so on together the new potential services such as traffic information, navigation, and interactive multim ould d to the customers via versatile mobile terminals in global areas crossi , home, erprise spaces, etc [IST04a].

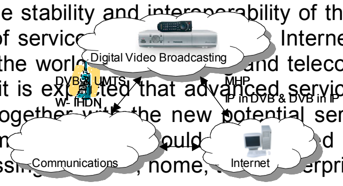

Figure 10: DVB in 3G Convergence Network

3.2.4 Network Fusion

The technology development of information and communication results in the network fusion, that is, the same infrastructure is able to supply different services. Unlike in the traditional network where different infrastructure has been specified to meet the specific service requirement, the innovative network is able to support various services in order to minimise the operation cost and increasing the network capacity.

DVB is addressing the technology development with respect to mobile communication in terms of synergetic utilisation of DVB and cellular (GPRS, UMTS) systems in DVB ad-hoc group (AHG) [DVB02]. 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, WLAN system that plays more and more important role in wireless communications is taken into account in DVB activities.

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, fusion network will benefit not only from the existing Internet applications, but also the impulse of the development of new services. DVB-over-IP and IP-over-DVB are currently being development and standardised. The former refers to the delivery of digital television services over broadband IP networks. Typically it will be over cable network so the supplier can achieve the bundling services including VoIP, telephone as well as Internet with the digital television service. The later 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 data services such as file transfers, multimedia, and Internet.

3.3 Fusion Network Scenarios

3.3.1 Fusion of Digital Video Broadcasting and Internet QoS

In this section, we consider a GEO satellite inter-worked with terrestrial nodes. The satellite is endowed with DVB-RSC technologies, while ground stations are satellite terminals with DVB-RCS transceivers (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 frequency and time division multiple access technique (MF-TDMA).

It is worth noting that currently deployed DVB-RCS networks employ satellites with a transparent payload, so that they simply act as bent pipes, particularly suited for reaching remote location where terrestrial networks are not available, but also for long distance communications. However, additional capabilities are envisioned for the short term evolution of satellite payload. Regenerative payload systems, endowed with packet switching facilities, will become soon available on the market.

Hence, at present, the intelligence of actually deployed DVB-RCS satellites is concentrated on two specialised ground stations:

- the Satellite Terminal (RCST), where users physically access the satellite network, and which is responsible for the selection and the fine scheduling of the data to be transmitted, the QoS support and the initiation of resource request for each application;
- the Network Control Centre (NCC), where satellite connections are managed (and established, if needed), and which is responsible for the generation of a Terminal Burst Time Plan (TBTP) for the management of transmission slots assigned to each RCST interconnected to the NCC. The TBTP is also compatible with the on-board switching requirements and the signalling procedures for the resource allocation in a MF-TDMA shape.

The reference network scenario is depicted in Figure 11. The picture represents a DVB-RCS satellite and its coverage area (i.e., for the sake of simplicity, we assume that a single satellite is adopted, with a single spot beam). The NCC operates as a gateway to the Internet, while each satellite terminal can provide connectivity to one or more users located in a LAN and 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.

3.3.1.1 Interworking of IP and DVB-RCS

Interworking between terrestrial and satellite QoS architectures is strongly affected by the mechanism of adaptation between network layer and data-link layer. Particularly, in this subsection we present the issues to be addressed in order to correctly design the interworking procedures, while in following subsections we will show how IP parameters can be mapped on DVB-RCS parameters, and how that mapping affects the QoS of each data flow. We will take into account the two most relevant QoS-oriented IP architectures: IntServ and DiffServ. Finally, we will show that an optimised interoperation of terrestrial and satellite terminals can be driven by the QoS characterisation of the adopted IP architecture (i.e. DiffServ or IntServ).

In case of IntServ adoption, the end user shall adopt a signalling scheme to notify its quantitative traffic and performance requirements, as derived by the invoked application. The satellite system should be able to interoperate effectively with RSVP (or an analogous reservation protocol adopted in the IntServ scenario), by means of a local admission control for satellite resources allotting. This is, RSVP reservation procedures should be effectively supported by means of local (satellite) reservation mechanisms, in order to correctly manage the traffic packets in terms of DVB-RCS capacity categories (i.e. bandwidth allocation mechanisms), and for a proper forwarding of the signalling packets.

In case of DiffServ adoption, the satellite system should be able to effectively interoperate with multiple DiffServ PHBs, with either static or dynamic access control to the available service classes. Since the only allowable parameter to determine the packet handling behaviour in a DiffServ network is the DSCP (DiffServ Code Point) label conveyed by the IP packet header (i.e. a replacement of the 8-bits TOS (Type of Service) field), the DVB-RCS system should be able to parse the meaning of DSCPs and map each IP packet on the appropriate MAC queue (i.e., choose the right DVB-RCS precedence, also named “Profile Class”). Similarly to the RSVP case, when DSCPs convey implicit signalling over data plane [BIA01], DVB-RCS has to handle any specific data-link layer issues related to the implicit signalling (e.g., looking for an existing and suitable DVB-RCS connection or possibly opening such a connection either for the forwarding of the signalling message or to reply to that message).

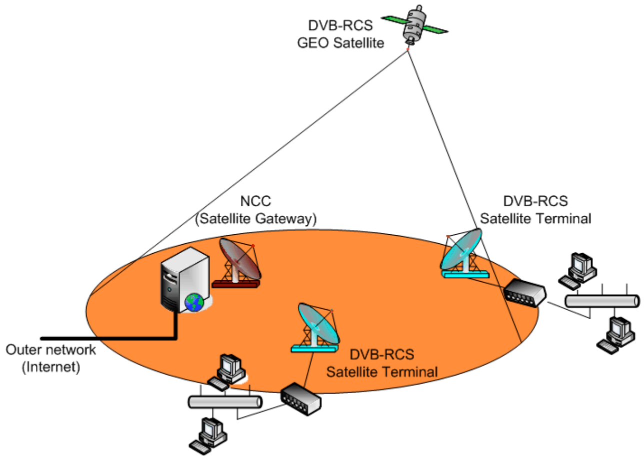

Figure 11: Network scenario

3.3.1.2 QoS in a DVB-RCS system

According to the presentation of the DVB-RCS L2-services (proposed in 2.2.3), a way to differentiate the service offered by a DVB-RCS node, is offered by the tuning of 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 we refer to a six-queues architectures which are needed in order to support the set of traffic classes, envisioned by ETSI in [ETS03a]:

i) real-time priority traffic;

ii) variable rate priority traffic, no jitter tolerant;

iii) variable rate priority traffic, jitter tolerant;

iv) jitter tolerant priority traffic;

v) other priority traffic;

vi) best effort.

In correspondence with these six categories, or classes, six profile classes are sketched in Table 3. Considering in the definition of those classes, the QoS parameters are:

- the maximum packet transfer delay, computed as the time due to move a packet between the extremities of the satellite link;
- the peak-to-peak delay variation (jitter), expressed as the maximum jitter experienced in the satellite link;
- the packet loss ratio (PLR).

It is worth noting that, based on the definition of DVB-RCS capacity categories reported in the description of the DVB-RCS service model, Profile Classes 1 and 2 are only supported by CRA (with different bandwidth specifications), since they cannot tolerate delay jitter. Profile Classes 3 and 4 can use a minimum guaranteed bandwidth (provided by CRA), a variable and impermanent extra bandwidth (to be negotiated through RBDC, when needed), plus a portion of the possibly spare bandwidth (with automatic FCA). Profile Class 5 has less stringent jitter requirements than Profile Class 4, so a combination of RBDC and VBDC or AVBDC can be adopted instead of RBDC, so that the guaranteed bandwidth is reduced. Eventually, Profile Class 6 has no requirements, so that volume based capacity assignment can be adopted, plus a possible exploitation of spare bandwidth.

Profile Class	**Delay**	**Jitter**	**PLR**	**Application example**	**Recommended capacity allocation method**
1	Highly sensitive (hundreds ms)	highly sensitive (some tens ms)	loosely sensitive ($\leq 10^{-3}$)	Voice-based	CRA
2	sensitive (≤ 1 s)	highly sensitive (some tens ms)	sensitive ($\leq 10^{-4}$)	Real time TV-cast, Interactive TV	CRA
3	sensitive (≤ 2 s)	loosely or not sensitive	highly sensitive ($\leq 10^{-6}$)	Real Time Transaction Data	CRA+RBCD+FCA
4	Loosely sensitive (few seconds)	not sensitive (no upper bound)	sensitive ($\leq 10^{-4}$)	Web Browsing, Interactive Games	CRA+RBDC+FCA
5	Loosely sensitive (some seconds)	not sensitive (no upper bound)	highly sensitive ($\leq 10^{-6}$)	File transfer	CRA+RBDC+(A)VBDC+FCA
6	not sensitive (no upper bound)	not sensitive (no upper bound)	not sensitive (no upper bound)	e-mail, Fax	(A)VBDC+FCA

Table 3: DVB-RCS network Profile Classes

The six Profile Classes are characterised in Table 3 following an approach related to the sensitiveness of each PC to the QoS parameters. Of course, 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.

There are basically two high performance Profile Classes (PC1 and PC2) which are particularly suited for real time applications offering a great amount of traffic. PC3 offers intermediate performance for real time applications and interactive applications requiring a small amount of data to be transferred, but which need higher protection against packet loss. Pleasurable support for web surfing is offered by PC4, as well as for instant messaging applications with slow rate video and interactive games. PC5 is definitely not suited for interactions and real time needs, but it suits for a better than best effort service, useful for file transfer or (medium-slow rate) Internet browsing. A BE service is actually provided by the PC6, without any kind of guarantees and bound for QoS parameters.

3.3.1.3 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) how to map IntServ services on DVB-RCS Profile Classes; ii) how to map DiffServ classes on DVB-RCS Profile Classes. The first point occurs when the satellite hop is under the direct control of the IntServ domain. The second point refers to a scenario in which the DiffServ sub-network also exploits the capabilities offered by the DVB-RCS connectivity. Finally, when a generic IP/DVB-RCS mapping requires a connection setup, or a resource reservation, the DVB-RCS MAC requires the knowledge of three main parameters: the Priority Class, the Peak Data Rate (PDR), and the Sustainable Data Rate (SDR). Following the description of Table 3, and in particular the rightmost column:

- priority is strictly needed;
- PDR is needed for CRA in case of Priority Classes 1 and 2, and for RBDC when Profile Classes 3 to 5 are used;
- SDR is used by CRA for Profile Classes 3 to 5;
- (A)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 Profile Classes 3 to 5. Conversely, MBS is not significant for Profile Classes 1 and 2, because of the delay jitter intolerance, and for Profile Class 6, 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” [ESA04a]. There we provide guidelines to mapping in terms of Profile Classes (including QoS parameters) and traffic parameters between IntServ or DiffServ service model and DVB-RCS service model.

3.3.1.4 QoS-related mapping between IntServ/RSVP and DVB-RCS

In this subsection, mappings in terms of Profile Classes (including QoS parameters) and traffic parameters between IntServ/RSVP service model and DVB-RCS service model are provided.

There are two possible mappings for GS: packets belonging to a Guaranteed Service session has to be conveyed through PC1 and PC2, because of the real time support required by GS. In DVB-RCS domain, the main difference between PC1 and PC2 is the maximum packet transfer delay value assured by DVB-RCS bearer service, which is some hundreds of ms for PC1 (for conversational applications) and less than 1s for PC2 (suitable for streaming and interactive TV services). Consequently a GS is proposed to be mapped into the DVB-RCS PC1 or PC2 according to the requested maximum packet transfer delay. Anyway, a conservative approach consists of using PC1 for every GS services. Conversely, PC3 to PC6 are not applicable for GS, since these classes do not provide stringent delay bounds and cannot guarantee consistently low delay for every packet.

In conclusion, the Guaranteed Service is mapped into DVB-RCS PC1 or PC2, 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 are conveyed by RSVP messages. In particular, the following mapping applies:

- If the DVB-RCS device uses buffers: $PDR_{DVB\text{-}RCS} = R$;
- elsewhere: $PDR_{DVB\text{-}RCS} = \max(R, p)$.

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

Since PC1 and PC2 are reserved to GS, there are three possible mappings for CLS: PC3 to PC5. PC1 and PC2 can still be used to accommodate CLS classes when GS service is not performed. In a DVB-RCS domain, the main difference between Profile Class 3 and Profile Class 4 and 5 is the maximum packet transfer delay requirement which is specified (even if it is not stringent) in the PC3 and not specified in PC4 and PC5. Considering that the applications (with loose delay requirements but which are highly sensitive to overload conditions) which require a CLS specify only the traffic characteristics (TSpec) while the reservation characteristics (RSpec) are not required, the choice among Profile Class 3, 4 and 5 can be made on the basis of i) the requested TSpec, ii) the available resources, and iii) the predefined correspondence rule which associates classes of applications to the Profile Classes. The Profile Class 6 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.

Thus, Controlled Load Service is mapped into DVB-RCS Profile Class 3 to 5, where traffic fluctuations are allowed, so that three parameters have to be mapped: PDR, SDR and MBS. These traffic parameters will result from the following RSVP/DVB-RCS mapping formulas:

$PDR_{DVB\text{-}RCS} = p$
$SDR_{DVB\text{-}RCS} = r$
$MBS_{DVB\text{-}RCS} = b$

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.

Table 4 summarizes the proposed mapping between IntServ/RSVP classes and DVB-RCS Profile Classes. It can be noted that, even though all of the Profile Classes have the capability to carry Best Effort service, the natural Profile Class is the DVB-RCS Profile Class 6 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.

	IP Classes	DVB-RCS Profile Classes					
		1	2	3	4	5	6
IntServ Classes	GS	√	√				
	CLS			√	√	√	
	BE						√

Table 4: Mapping of IntServ/RSVP classes to DVB-RCS Profile Classes

3.3.1.5 QoS-related mapping between DiffServ and DVB-RCS

In this subsection, accordingly to [ESA04a], guidelines to mapping in terms of Profile Classes (including QoS parameters) and traffic parameters between DiffServ service model and DVB-RCS service model are provided.

As to traffic parameter mapping, it is worth noting that in a DiffServ domain, only traffic aggregates can be managed. As a consequence, predefined traffic parameters have to be considered, and the network operator provides default values. One solution consists of distributing the available bandwidth between DiffServ classes, following a predefined percentage repartition. This repartition depends on the number and the types of implemented DiffServ classes. Once a new connection has to be established, each terminal can use a different, but locally predefined set of connection parameters. Subsequent parameter renegotiation should be allowed. In every case, the only required parameter to signals is the bandwidth. Since DiffServ networks make use of multiple DSCPs and only a few number of PCs can be provided by a DVB-RCS node, a many-to-one relationship is set between DSCPs and DVB-RCS Profile Classes: a DSCP corresponds to one and only one Profile Class, but multiple DSCPs can be mapped on a single Profile Class.

EF PHB should be considered the equivalent of GS in IntServ. As a consequence, there are two possible mappings for EF PHB: Profile Class 1 and Profile Class 2, because of the real time support and stringent delay requirements. As already seen, in DVB-RCS domain, the main difference between Profile Class 1 and Profile Class 2 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 Profile Classes 3 to 5, plus the additional Profile Class 2 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 twelve 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.

Actually, we recall that DiffServ packets belonging to a given AF class share the same queue at IP level, and a precedence differentiation is enforced between three “precedence levels” while entering the IP queue. Thus 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 [BIA01, MAN04a]. The rules driving this differentiation are defined below.

In Table 5 to Table 6, two configurations are considered, taking into account all AFxy DSCPs (Table 5), or just a minimal set of AF DSCPs (Table 6), plus EF and BE DSCPs. Note that in Table 5 a single AF class is mapped onto two PCs: one for AFx1 (higher performance) and one 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”, proper of the RCST, determines the IP QoS level of an incoming flow by analysing the information contained in the DSCP field. After processing of the DSCP field, the RCST knows the type of service requested by a new flow and it may determine a suitable associated Profile Class.

In Table 6 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.

Table 6 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).

DiffServ Classes		DVB-RCS Profile Classes					
Class	Prec.	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 5: A possible mapping of DiffServ classes to DVB-RCS Profile Classes

DiffServ Classes		DVB-RCS Profile Classes					
Class	Prec.	1	2	3	4	5	6
EF		√					
AF1	Data (1)		√				
AF1	Other (2)			√			
AF2	Data (1)				√		
AF2	Other (2)					√	
BE							√

Table 6: An alternative mapping of DiffServ classes to DVB-RCS Profile Classes, using a minimal DiffServ set

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 Profile Class from IntServ/RSVP-to-DVB-RCS mapping table, obtaining a given Profile Class, 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, let’s consider the mapping proposed in Table 5 and a CLS service. Following Table 4, 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 5 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.

3.3.2 Mobility Management in Fusion Network

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 [ITU99], several fundamental requirements and parameters for handover was outlined, such as the parameters for radio channel quality estimation, parameters for quality of service assessments and location data management, etc. 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 addition, how the parameters can be obtained using standard simple network management protocol (SNMP) will be described [IET02].

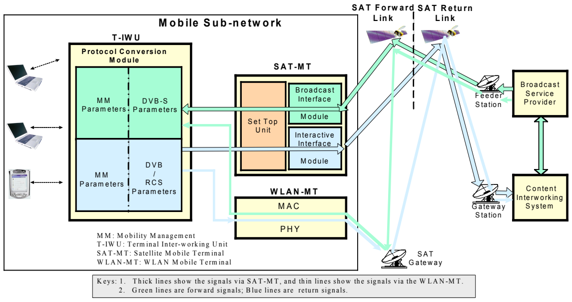

Figure 12: System Architecture for Protocol Conversion [IST04b]

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. Such a fusion network comprised of DVB and WLAN systems is taken as the baseline scenario used in this section. Two continuous major typologies of service (Internet and broadcast digital TV) can be provided over the fusion network to a mobile sub-network (e.g. It 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.) [IST04a]. 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 the satellite link unavailable area. As shown in Figure 12, two channels are established between the service provider/content interworking system and the mobile sub-network [ETS03].

- 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, protocol conversion module is inside the terminal inter-working unit (T-IWU), which is the nomadic middleware between the mobile sub-network and the network control centre (NCC) 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 ways of protocol conversion are considered. One is in the forward direction to map the DVB-S parameters with the MM parameters. The other is for the return path to map the MM parameters with the DVB-RCS 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 [ETS03] such as:

- Special transport stream packets (program clock reference (PCR) insertion).

- Descriptor, including private descriptors for standard DVB-SI tables.

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 [ETS03a] [IET02]. They are also used between the T-IWU and RCST to obtain the current system configuration parameter values to assist the protocol conversion.

As shown in Figure 13, SNMP [IET02] and SI access application programming interface (API) specified in [ETS03b] 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. **Errore. L'origine riferimento non è stata trovata.** is the mapping of MM parameters defined in ITU standards and DVB parameters in DVB systems.

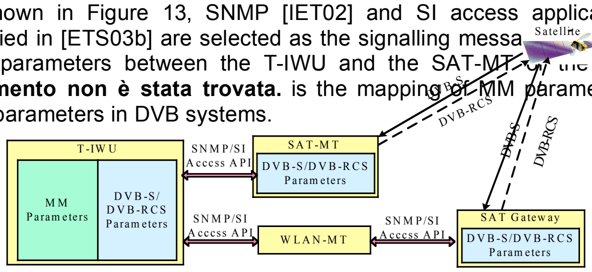

Figure 13: Messages Used in Protocol Conversion

Parameters of MM defined in ITU standards [ITU99]	Parameters of DVB-S / DVB-RCS	DVB Standards that Mapped onto [ETS03] [ETS03a]	Definition / Description

Position of MT	RcstSysInstallLocation (Preferred)	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB	Physical location of the ODU antenna expressed as Cartesian coordinates x, y, z, in the geodetic reference frame ITRF96 (IERS Terrestrial Reference Frame). The Installation Team shall assign the location value to this variable. Floating-point notation shall be used. Format: x<space> y<space> z. Values in metre. Modification of geographical re-location may require an update of those SNMP objects.
	sysLocation	ETSI TR 101 790 v 1.2.1 (2003-01); F.5 MIB-II	The Physical location of the IDU, including street address and GPS co-ordinates expressed as Cartesian co-ordinates x, y, z in the geodetic reference frame ITRF96 (IERS Terrestrial Reference Frame). The Installation Team shall define it-floating-point notation. Format: x<space> y <space> z. Values in metre.
Timestamp	rcstLifeRcstStatusCurrentTimestamp	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB	Timestamp indicating at what time the current operational status has been reached by the RCST. Every time the RCST status changes, the value of this object shall be assigned to rcstLifeRcstStatusPreviousTimeStamp and then updated to be equal to the sysUP Time MIB-II object value.
Segment Status	rcstLifeRcstStatusCurrent	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB	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.
Bandwidth Availability	ifSpeed	ETSI TR 101 790 v1.2.1 (2003-01); F.5 MIB-II.	Estimate of current bandwidth in bits per second.

Delay	Propagation_delay	ETSI EN 301 790 v 1.3.1 (2003-03); 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 Type / MT Record Data	rcstSysTargetEbNO	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB.	This value describes the wanted Eb/No value that enables operation of the return link with the required error performance.
	rcstSysEbNORange	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB.	This value describes the possible range of Eb/No variation that can be compensated by the system.
Target Segment Record	ifSpeed	ETSI TR 101 790 v1.2.1 (2003-01); F.5 MIB-II.	Estimate of current bandwidth in bits per second.
	ifOperStatus	ETSI TR 101 790 v1.2.1 (2003-01); F.5 MIB-II.	The current operational state of the interface.
	ifInErrors	ETSI TR 101 790 v1.2.1 (2003-01); F.5 MIB-II.	The number of inbound packets discarded because they contain errors.
	ifOutErrors	ETSI TR 101 790 v1.2.1 (2003-01); F.5 MIB-II.	The number of outbound packets discarded because of the errors.
	Propagation_delay	ETSI EN 301 790 v 1.3.1 (2003-03); 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.

	EbNo	ETSI EN 301 790 v 1.3.1 (2003-03); Section 8.5.5.10.3. Correction Message descriptor	This 7-bit field gives the measured Eb/No value on the return link.
Time Before Link Loss	rcstActTrafficRelease Timeout	ETSI TR 101 790 v 1.2.1 (2003-01); F.4 Private Enterprise RCST MIB.	Time, specified in milliseconds, after which the RCST shall release its Traffic VCC due to no traffic from hosts bound for the Return Link, while one or more entries remain in the Host Authentication table.
BER	ifInErrors	ETSI TR 101 790 v 1.2.1 (2003-01); F.5 MIB-II.	The number of inbound packets discarded because they contain errors.
	ifOutErrors	ETSI TR 101 790 v 1.2.1 (2003-01); F.5 MIB-II.	The number of outbound packets discarded because of errors.

Table 7: Mapping of MM parameters and DVB Parameters

4 RESEARCH DIRECTIONS

Future fusion 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 composed of different access platforms. The evolution of mobile communication to all-IP networks to enable service operated in various networks will become an important issue for the future broadband mobile communications and the growth of Internet. IP-based mobility management is required to guarantee service continuity even when the access network is switched while the consumer is moving. For instant, specific fast handover strategies is required to conquer the limitation of mobility function in assist of seamless and continuous data service when a consumer is on the high-speed move. In heterogeneous networks, particular handover strategies suited for different access network are mixed. Therefore, an adaptive and smart handover control mechanism is necessary to act as a 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 [PAR03]. 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 on fast Mobile IP handover algorithms to minimise the processing delay of Mobile IP is necessary in next-generation fusion network [ITU04]. Moreover, because of the instinct weakness of IPv4 (limited address space), to expedite a worldwide IPv6 movement in the next-generation fusion network is another important issue. Several research challenges in the different layers are summarised in Table 8.

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

Table 8: Challenges in A Fusion Network

In terms of development in 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 European telecommunications standards institute (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 [ETS05] 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, 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 seam-less provision of security, quality of service, address resolution, and multicast support. This work is now proceeding for IPv4, and it is anticipated 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 specification of the framework [MON05] and ULE protocol [FAI05], the WG is currently focussing 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.

5 Conclusions

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 of satellite broadcasting technology with standard IP protocols will enable the smooth integration of satellite services with mobile and Internet technologies. In this tutorial paper, several current and possible future operational scenarios comprising of a DVB-S systems has been discussed, where issues related MM and QoS have been addressed.

Acronyms and Abbreviations

1G	first generation
2G	second generation
3G	third generation
AAA	authentication, authorisation and accounting
AAL	ATM adaptation layer
AAL5	ATM adaptation layer 5
ADSL	asymmetrical DSL
AF	assured forwarding
AHG	ad-hoc group
API	application programming interface
AVBDC	absolute volume based dynamic capacity
B3G	beyond 3G
BE	best effort
BGAN	broadband global area network
CDMA2000	code division multiple access 2000
CLS	controlled load service
CRA	continuous rate assignment
CSC	common signalling channel
DiffServ	differentiated services
DSCP	DiffServ code point
DSL	digital subscriber line
DVB	digital video broadcasting
DVB-RCS	DVB return channel by satellite
DVB-S	digital video broadcasting via satellite
DVB-S.2	second-generation DVB system for broadband satellite services
EDGE	enhanced data for global evolution
EF	expected forwarding
E-GPRS	enhanced GPRS
ETSI	European telecommunications standard institute
EV-DO	evolution data optimised
FCA	free capacity assignment
FCC	federal communications commission

FTTB	fibre to the business
FTTH	fibre to the home
GEO	geostationary earth orbit
GGSN	gateway GPRS support node
GPRS	general packet radio service
GSM	global system for mobile communications
GS	guaranteed service
HiperLAN	high performance LAN
IntServ	integrated services
IP	Internet protocol
ISM	industrial, scientific and medical
IT	information technology
ITU	international telecommunication union
LLC	logical link control
MBS	maximum burst size
MHP	multimedia home platform
MIB	management information base
MM	mobility management
MPTD	maximum packet transfer delay
MSS	mobile satellite service
MT	mobile terminal
NCC	network control centre
p	peak rate
PC	profile class
PCR	program clock reference
PDA	personal digital assistant
PDR	peak data rate
PHB	per hop behaviour
PLB	power line broadband
PLR	packet loss ratio
PtPDV	peak-to-peak delay variation
QoS	quality of service
R	guaranteed rate
RBDC	rate based dynamic capacity

RBGAN	regional broadband global area network
RCST	return channel satellite terminal
RSVP	resource reservation protocol
RTT	radio transmission technology
SAT-MT	satellite mobile terminal
SatNEx	satellite communications network of excellence
SDR	sustainable data rate
SDSL	symmetrical DSL
SHDSL	symmetric high-speed DSL
SI	service information
SI-SAP	satellite – independent service access point
SNMP	simple network management protocol
TBTP	terminal burst time plan
TDMA	time division multiple access
TIM	terminal information message
T-IWU	terminal inter-working unit
ToS	type of service
UMTS	universal mobile telecommunications system
UWB	ultra wideband
VBDC	volume based dynamic capacity
VDSL	very high-data-rate DSL
VoIP	voice over IP
W-CDMA	wideband code division multiple access
Wi-Fi	wireless fidelity
W-IHDN	wireless in home digital network
WiMAX	worldwide interoperability for microwave access
WLAN	wireless local area network
WLAN-MT	WLAN mobile terminal
WMAN	wireless metropolitan area network
WWW	world wide web

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