Multi-layer Resource Management in DVB-S.2 Networks: The IMOSAN approach

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Abstract

The ACM (Adaptive Coding and Modulation) feature of the DVB-S.2 technology for digital satellite broadcasting enables for dynamic, real-time management and adaptation of the physical-layer parameters in order to achieve a guaranteed QoS at the reception site. The EU-funded IST IMOSAN project will not only exploit this feature but also extend the approach of resource management in a multi-layer architecture (physical, network, application). This multi-layer resource management scheme will be applied in a DVB-S.2/RCS network to optimise the provision of triple-play services.

Keywords

Multi-layer resource allocation, bandwidth optimisation, satellite networks, triple play services

1. Introduction

The wide coverage area and high bit rate capabilities make satellite links an ideal medium for the provision of a variety of services, to urban an rural areas (Clausen et al, 1999). As a consequence, there is increasing commercial interest to use satellites in modern communications. However, this strong commercial interest is balanced by the cost of the lease of satellite transponders and by the time-variation of satellite channels, especially near the bounds of the satellite footprint, which affects the performance of the whole system. The success of satellite communications is heavily dependent on new solutions that : (a) maximize the efficiency of satellite spectrum, which reduces the cost of satellite link per service or per user and (b) use adaptive channel coding techniques to compensate for the time variations of the satellite channel.

No complete and unified solution that maximizes the efficiency of the satellite transponder and compensates for time variations exists today. The problem has been –and is currently being– investigated in many layers (physical, network, service), but only partial solutions have been proposed so far; the solutions provide optimisation in special cases, where, for example, only one of the above layers is considered, or a static channel is assumed (Xu and Tonjes, 2000; Negru and Roul, 2002,).

The EU-funded IST IMOSAN (Integrated Multi-layer Optimization in broadband DVB-S.2 SAtellite Networks) project (IMOSAN Homepage, 2006), currently running under the 6th

Framework Programme, addresses this issue by designing and implementing a multi-layer resource management mechanism and incorporating it in a DVB-S.2/RCS network.

2. The IMOSAN concept

In specific, the IMOSAN project proposes an integrated management solution that allows optimum usage of the satellite spectrum, which spans across three layers: physical, network and service. This multi-layer optimization will be based on the capabilities of DVB-S.2 standard and will be performed in an integrated and coherent way for all layers, using a Satellite Resource Management System (SRMS). Adaptive coding and modulation (ACM) features of DVB-S.2 standard will be exploited, to provide optimization in time varying operating environments. An actual DVB-S.2 satellite network will be developed, to demonstrate and validate the capabilities of the multi-layer management solution, for the provision of triple play services, digital TV programs, Internet access and telephone connections, under real conditions. The return channel will be based on DVB-RCS technology and the DVB-S.2/DVB-RCS gateway will be incorporated, upgraded with SRMS and tested. The performance of the network will be tested and evaluated through triple play services, as well as through a tele-learning application.

An overview of the proposed integrated multi-layer management concept is depicted in Figure 1. Measurements for the condition of the forward satellite channel, received through the return channel, will be exploited by the SRMS and appropriate actions will be taken to optimize the satellite channel, by proper adaptations in the :

- physical layer (modulation, FEC, etc),
- network layer (dynamic bandwidth management per service, or per user, etc)
- services layer (bit rate, resolution, format, etc).

A services priority list will be taken under consideration.

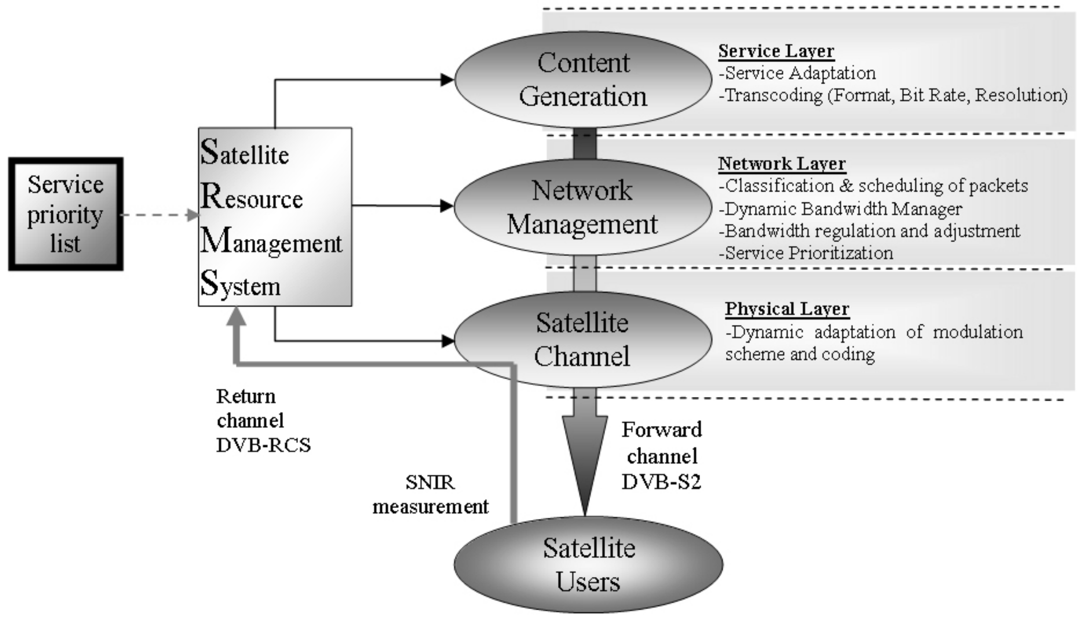

Figure 1: Overview of the IMOSAN integrated multi-layer management concept, for optimizing the usage of satellite spectrum

Recent technological achievements in the fields of channel coding, network management and video encoding techniques will be used and exploited in IMOSAN project. In the physical layer, the emerging second generation specification for satellite broadcasting, DVB-S.2, will be considered. A powerful FEC system (based on LDPC codes concatenated with BCH codes) and higher order modulation schemes (QPSK, 8PSK, 16APSK, 32APSK) will be employed. This combination enables Quasi-Error-Free operation at about 0,7dB to 1 dB from the Shannon limit, depending on the transmission mode. The latest improved developments achieve a 30% increase in spectral efficiency over DVB-S, at a given transponder bandwidth and transmitted EIRP. Variable Coding Modulation (VCM) will allow the provision of different level of error protection to different service components (e.g. SDTV and HDTV, audio, multimedia). IMOSAN will also exploit the Adaptive Coding Modulation (ACM) capability of DVB-S.2, for interactive applications, providing more exact channel protection and dynamic link adaptation to propagation conditions, targeting each individual receiving terminal or area. The exploitation of ACM capabilities is expected to provide satellite capacity gains of up to 100%-200%, for interactive services. A feedback loop mechanism will enable the SRMS to be informed about the forward channel condition (e.g. Signal to Noise and Interference ratio, SNIR) of each satellite terminal, via the DVB-RCS link, in order to take the appropriate actions.

In the network layer, data rate limiting, dynamic bandwidth management techniques and service prioritization mechanisms will be used, to allocate the appropriate bandwidth to each service (for broadcast and multicast) or to each user (for interactive/unicast applications). MPE (Multi Protocol Encapsulation) and ULE (Unidirectional Lightweight Encapsulation) protocols will be simultaneously supported, as well as both IPv4 and IPv6 datagrams.

In the service layer, recent video encoding techniques (MPEG-4/AVC, H.264) will be used to minimize the required encoding bit rate for video services, while keeping the quality at high level. Furthermore, transcoding solutions, on the fly, will be used to allow the best possible adaptation of audio/visual services, according to the variations of the satellite channel capacity.

IMOSAN intends, not only to use various modules, tools and techniques in the physical, network and service layers, but to integrate their functionalities, in order to enable the optimisation of the satellite spectrum efficiency.

The SRMS system to be designed, implemented and developed will be demonstrated and evaluated in a real satellite environment. A star topology network will be implemented, among nodes in Toulouse (France), Athens (Greece), Paris (France), Heraklion (Greece) and Cluj (Romania).

3. Network architecture

The general architecture of IMOSAN is shown in Figure 2. It comprises of :

- A DVB-S.2/DVB-RCS Gateway (GW), which provides the basic ground infrastructure, required to handle broadband access services. The GW manages a number of sub-networks in a star configuration. The forward link (from GW to Satellite Terminals) is based on DVB-S.2 technology, while the return link (from STs to GW), is based on DVB-RCS technology. The GW provides satellite resource management, equipment management and interface with the Satellite Terminals. A Bandwidth Manager and Multiplexer module (BWMM), to be developed, will receive and multiplex two types of services : IP based interactive and TV broadcast services. The IP based services (Internet, VoIP, Interactive multimedia) will be managed by the BW manager module (internal to BWMM), encapsulated and passed to the multiplexer as multiple transport streams, one per protection level. TV services, properly adapted by service Adaptation modules (SA) also feed the Multiplexer. The Transport streams are properly processed (NP deletion, merging etc) and passed to the DVB-S.2 modulator, which provides the appropriate channel coding and adaptation in the forward link. In the return link, a Burst Multi-carrier Demodulator (BMD) receives and demodulates the DVB-RCS traffic (Requests, ACKs) from the Satellite Terminals (ST) (Adami et al, 2005). An appropriate module (SNIR measurement) will be responsible for capturing data concerning the Signal to Noise and Interference Ratio (SNIR) measurements, coming from the STs. These data will be exploited by the SRMS.

- An SRMS module, which performs the integrated management of the satellite network resources. The inputs of this module are the ACM signals (SNIR measurement), received through the return channel, and a service prioritization list. If SNIR measurements indicate a change in the satellite channel conditions, the SRMS will calculate the appropriate encoding parameters and bandwidth requirements for each service or user, according to the prioritisation list. Then, it will issue the appropriate commands to the Bandwidth Manager and Multiplexer (BWMM) and to the Service

Adaptation (SA) modules. The appropriate control data will be sent to the DVB-S.2 modulator though the BWMM module, in order to achieve the proper adaptation in all layers, according to the satellite link conditions.

- Services generation modules. Triple play services will be provided through IMOSAN : telephony, fast access to Internet and TV programs. A VoIP gateway will be the interface between IMOSAN platform and PSTN, offering telephony services to end users. The VoIP traffic will pass through the bandwidth management module (controlled by the SRMS), in order to ensure the appropriate QoS. Apart from Web access and e-mail, a tele-learning application is anticipated to be provided over the IMOSAN network. An Applications Server will host the tele-learning application, as well as other interactive services like VoD and FTP. The traffic of these services will pass through the BW manager, where it will be dynamically managed. Finally, TV services are assumed to be available at the GW, either locally generated or arriving there through terrestrial high bit rate lines. A Service Adaptation (SA) module, under the control of SRMS, will perform all the appropriate adaptations to the TV services, in order to fit into the available bandwidth without significant loss of quality.

- Satellite Terminals (ST) that provide subscriber access to the network. Each terminal can support a variety of connections, ranging from a single user to a sub-network. Triple play services (telephone, Internet, TV) can be provided. Using appropriate interfaces (router, Access Point, etc), the ST can play the role of a head-end distribution node, which will offer connectivity to one or more sub-networks of end users, through other types of terrestrial access networks e.g. LAN, WiFi, WiMAX, etc. Set-Top-Boxes (STB) will also be used to provide one-way broadcasting TV services.

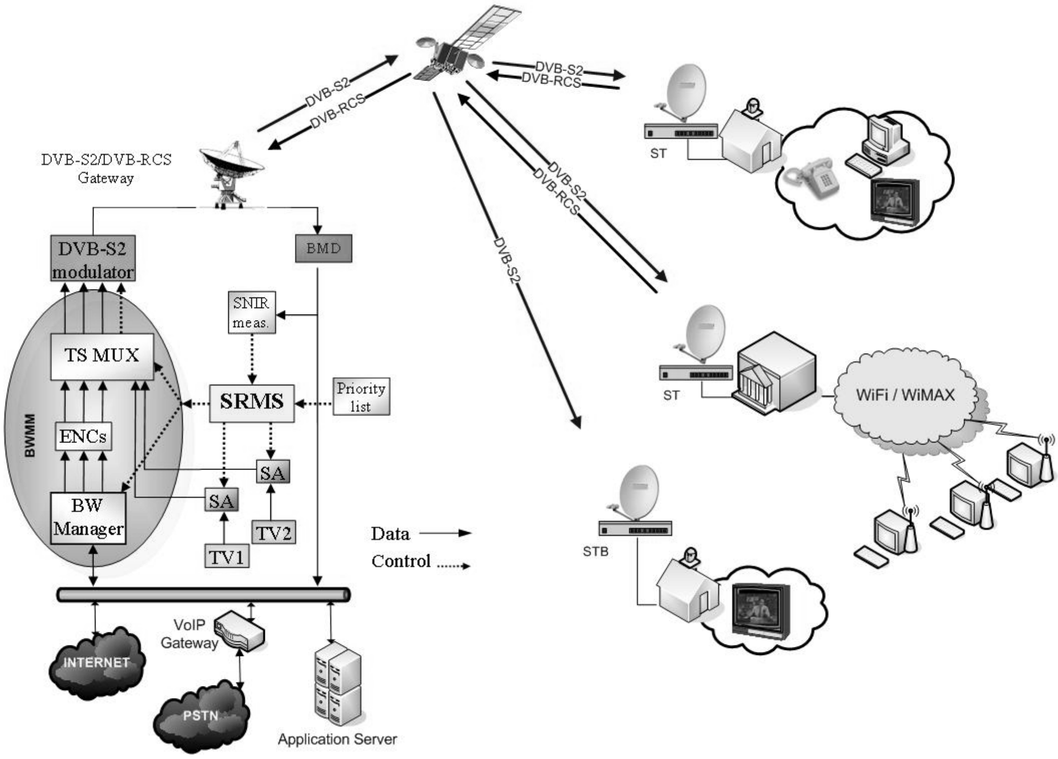

Figure 2: The overall architecture of IMOSAN, based on DVB-S.2/DVB-RCS technology.

IMOSAN proposes an optimised satellite access network, as a function of the operating environment. The improvement in the efficiency of the satellite spectrum, which is in the order of 30% for broadcasting services and 100%-200% for interactive services using ACM capabilities, is expected to significantly reduce the cost of satellite transponder per service or per user. This feature, in conjunction with a low cost DVB-RCS terminal is expected to provide affordable prices for satellite links, allowing for a generalized introduction of broadband services in Europe and in less developed regions, notably for the enlarged Europe in line with the eEurope objectives. IMOSAN intends to offer triple play services (telephone, Internet, TV) through a single platform to rural and less developed areas, where cabling/fiber optic infrastructures are not yet fully developed. The proposed architecture and infrastructure is scalable, expandable and interoperable with other technologies, e.g. WiFi/WiMAX.

4. Conclusion

This paper presented the concept and innovations of the EU-funded IST project IMOSAN, a research activity dedicated to developing a DVB-S.2/RCS Network with multi-layer resource management for the provision of triple play services.

By integrating technical solutions and services provision (triple play services), the project intends to make a breakthrough in satellite communications and accelerate the introduction of

DVB-S.2 technology, in the market. It is anticipated that this will facilitate the creation of a new market, especially (but not only) addressing rural areas and developing countries and ultimately fulfil the needs of large groups of European citizens.

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