Enhanced IP-based satellite architecture compatible with many satellite platforms

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ABSTRACT

In this paper the architecture of the IST-BRAHMS project (Broadband Access for High speed Multimedia via Satellite) is described. BRAHMS aims at specifying an IP-based architecture for broadband satellite access independently of the particular satellite technology adopted in the satellite link. Its goal is to promote integration and harmonization of many access network services and functions, whilst allowing flexibility for optimized or proprietary air interfaces This objective is achieved by supporting a choice of several RTD (Radio Technology Dependent) access technologies through a common set of RTI (Radio Technology Independent) protocols.

I. INTRODUCTION

Driven by the growth of the World Wide Web and the Internet, most of the satellite revenues in the next years are expected to come from the transport and delivery of IP-based applications and services, either to seamless complement the available terrestrial broadband services, or to propose, in some niche markets, added-value services. Thus, the challenge for the Next Generation satellite systems is finding an efficient integration in IP based Next Generation Networks. Research has delivered a number of proprietary solutions, which in the satellite field are hardly open to the public. Compatibility issues have to be evaluated carefully and in this context IP is seen as the common denominator which will drive future applications into a platform-independent transport scheme. Optimization of IP transport over a generic satellite technology then becomes a goal of primary importance.

This paper proposes a general model for an IP-oriented satellite architecture in which a range of existing and future satellite technologies can be accommodated and exploited by IP-based applications. This paper describes the architecture of the BRAHMS project, sponsored by EU in the framework of IST research programme. The overall scenario, the Broadband Multimedia Satellite System (BMSS) depicted in Fig. 1, is defined to promote integration and harmonization of many access network services and functions (e.g. QoS, multicast, roaming, security) whilst allowing flexibility for optimized or proprietary air interfaces (i.e. frequency, access type, orbit, space segment architecture, etc.). The depicted scenario is intended to support a choice of several RTD (Radio Technology Dependent) radio access technologies through a common set of RTI (Radio Technology Independent) protocols, which present common interfaces at the periphery of the system

II. OVERALL SYSTEM AND BRAHMS ARCHITECTURE

This paper aims at defining a satellite access network architecture for broadband services by adapting and further developing the Generic Radio Access Network (GRAN) approach. In this concept, the RTI parts are intended to be "universal", i.e. the same RTI parts can be connected to any RTD parts of the system, while the RTD parts will be specialized for a particular satellite link.

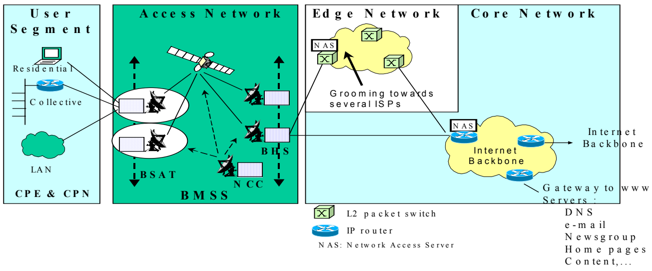

Fig. 1. Overall System Architecture

The Internet access-oriented architecture is constituted by four segments, as depicted in Fig. 1, described hereafter:

1. The **User Segment,** which includes all entities requiring access to a network, through standard IP devices.
2. The **Access Network (e.g. BMSS),** which adopts various terrestrial technologies, e.g. PSTN, ISDN, wireless access networks, ADSL etc. The Satellite Access Network includes the following *subsystems,* whose protocol stack is depicted in Fig.2:
   - The user-side access terminal equipment, referred to as *BMSS Satellite Access Terminal (BSAT),* interfacing with a *Customer Premises Equipment (CPE)* through standard protocols as PPPoE, PPP/USB, and IP/Ethernet.
   - The network-side access equipment, referred to as *BMSS Hub Station (BHS)*, interfacing with routers with transport protocols as ATM over SDH, ATM over ADSL, or Ethernet on the core network side.
   - The *satellite payload*, which can be transparent, providing layer 1 connectivity (at frequency channel, carrier, or time-slot level), or regenerative, providing layer 2 packet connectivity. In this last case the connectivity can be more dynamic.

3. The **Network Control Center** (**NCC**), which manages the operation of the satellite network including the satellite as well as the ground stations; this is assumed to be entirely dependent on the satellite technology
4. The **Core Network** includes all the "Internet networks", themselves connected to the Internet Backbone and composed of routers, servers and gateways towards the Internet Backbone. These networks are ISP, corporate or other types of networks.

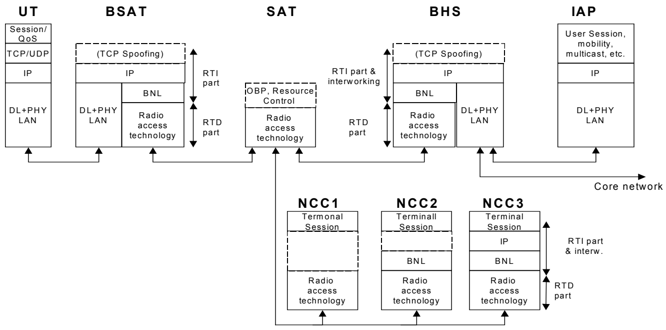

Fig. 2. BMSS protocol stack

III. BSAT FUNCTIONAL CHARACTERISTICS

The BSAT is the network equipment allowing devices on the User Segment to access the satellite segment. A BSAT interfaces with costumer premise devices via standard IP to support interworking of the satellite segment with a wide range of terrestrial link-layer technologies. Dynamic resource allocation procedures can be arranged depending on the type of terminals in the User Segment adopting an IntServ [1][2] or DiffServ [3][4] QoS approach through RSVP message exchange. BSAT functionalities can be divided into two distinct areas, namely the Radio Technology Dependent and Radio Technology Independent parts. The RTI design shall be oriented so as to allow convergence with a variety of radio access technologies.

IV. RTI-RTD: BMSS NETWORK LAYER (BNL)

The BNL interfaces with the IP layer and the satellite platform on the satellite link side. It performs IP-flow classification, IP performance enhancing functions and adaptation of IP over satellite platforms. A BNL entity in the BSAT is in communication with its peer entity in a BHS, and is responsible for transmitting and receiving control information and data across the Satellite segment. BNL functionalities are distributed in the *Control* and *User Plane*, where the former is in charge of handling RTI signaling to control the RTD resource management policy, while the latter has to process IP datagrams and adapt IP QoS techniques to the specific RTD traffic management mechanisms, by means of a configurable architecture.

The BNL is divided into two sub-layers, the *BNL-Common Part* and the *BNL-Specific Part*. The *BNL-Common Part* performs all those functions that are common to the BMSS. It is thought to provide a common basis for the BNL-SP parts which, instead, are configured to provide adaptation to a particular satellite technology. The BNL-CP contains functionalities that can be activated in order to enhance performance of IP streams over a satellite link. These can include IP header compression [5], TCP PEPs (Proxy Enhancing Performance), signaling overhead reduction, etc. The *BNL-Specific Part* constitutes the Radio Technology Dependent part of the BNL. It performs the same functions for any satellite platform but configured to achieve adaptation to the RTD parts. In particular, adaptation is needed to render the transfer modes that is provided by the RTD part transparent to the upper layer, i.e. if the underlying technology is connection-oriented or connection-less. Another form of adaptation is needed to configure multiplexing and demultiplexing of IP flows onto satellite bearers, which could vary in the number and in the degree of QoS provision.

User Plane functionalities

As far as concerns the user plane, the BNL is mainly concerned with the Traffic Control Mechanisms, TCP PEP (e.g. TCP spoofing), Data Unit compression/decompression and Data encryption/decryption. As to the Traffic Control Mechanisms, they are located in the BNL-Specific Part. The rationale for this choice is that BNL design has the purpose of enriching RTD functionalities, avoiding duplication of functions where possible. Therefore, if the underlying RTD platform has sophisticated traffic control mechanisms, like in the case of an ATM-based system, the set of functionalities to implement in the BNL-SP traffic control should be reduced to the minimum. In addition, the multiplexing/demultiplexing strategy of IP flows onto and from satellite bearers is dependent on satellite technology. Examples of blocks constituting the traffic control entity are: *Policing blocks, Classifier*, *Shaper*, and *Scheduler* [1].

Control Plane functionalities

The complexity of the functions performed by this plane basically depends on the transfer mode adopted by the RTD platform. When the RTD platform has no switched connection capabilities, no connection establishment operations are required. Therefore, the BNL-SP will not be able to control the RTD resource management policy. In case RTD platform provides switched connection capabilities, BNL-SP has to perform (i) interworking with the RTD signaling protocol entities in order to hide the channel establishment/tear-down peculiarities to the BNL-CP mechanisms, (ii) translation of the BNL QoS parameters into RTD specific QoS parameters, required for connection establishment in the RTD part. In the BNL-CP sub-layer, a set of functionalities dealing with the adaptation of RSVP protocol to the satellite environment has been provided. Although RSVP module lies on top of the BNL, some extra functionalities in the underneath control plane are necessary to make the use of RSVP convenient for the BMSS.

V. RTD

Due to the number of satellite platforms that can be supported by the BMSS, it is not possible to make a general characterization of the RTD part. However, a first distinction is among connection-oriented systems, from those which do not require connection establishment. As far as concerns the first systems, these provide satellite terminal with switching capabilities and resources can be assigned dynamically. Conversely, the second systems have a simpler architecture, since resources cannot be requested but are statically assigned to each terminal. In the following we will assume a connection-oriented RTD part so as to examine a richer and more complex set of functionalities.

Control Plane functionalities

As far as the control plane is concerned, the main task that the RTD part has to carry out is to manage allocation of resources and establishment/release of channels. In a connectionless transport scheme, this part of the system is remarkably simpler, since no channel establishment is needed. Regardless of the nature of the RTD system, several data channels have to be offered to the BNL layer. These channels are identified by the *Channel ID* (CI), used for routing in the satellite link, and the *Service Access Point Identifier* (SAPI), indicating the service type to be offered for the frame transport. The resource allocation policy could vary from a simple static allocation to a more complex strategy governed by a congestion control algorithm. This exploits statistical multiplexing of switched packets to optimize satellite resource utilization. An efficient allocation of resources could assign a minimum share of bandwidth to specific satellite bearers plus an additional variable portion to contend among competing bearers. The congestion control algorithm should monitor the state of load of the satellite link and take actions to control delay introduced by statistical multiplexing and prevent buffer overflows. Resources to be monitored carefully are especially those belonging to the satellite payload, which is provided with limited resources and located at the center of a star topology and, hence, likely to be considerably loaded by surrounding BHSs and BSATs.

User Plane functionalities

A BSAT is designed to provide transport of IP datagrams, which have variable-length format. As radio capacity is often shared on time-multiplexed channels having fixed time-slots, IP datagrams should be fragmented into fixed-size cell. Therefore, an assumption that will be made in the paper is the presence of segmentation and reassembly functions in the RTD part. This, however, is not a requirement to be necessarily satisfied by the RTD part. Segmentation and Reassembly is only one of the possible framing operations performed by the RTD part. On transmission into the radio channel, packets are likely to be scheduled according to their L2 address or CI and their priorities.

Management plane functionalities

Due to the broadcast nature of satellite systems, the radio interface must support the following security features:

- *Confidentiality of subscriber and identities*, to ensure that the identities are not disclosed to unauthorized parties.
- *Subscriber and user authentication*, to provide support for the verification of subscriber and user identities.
- *Confidentiality, to* ensure that the conveyed traffic (signaling, ordinary calls, data) is not made available or disclosed to unauthorized parties.

VI. BSAT ARCHITECTURE

In this section a detailed description of the BSAT functional entities and their relations is given. It is worth pointing out that each BHS is endowed with the same entities described for the BSAT subsystems; for this reason, and for readers' convenience, their description will be left out. In Fig. 3 horizontal dotted lines represent interfaces between layers, while vertical lines separate the three functional planes: User Plane (UP), Control Plane (CP), and Management Plane (MP). Rounded boxes (e.g. "ARP") represent entities, whereas square boxes with a bent corner (e.g. "Routing Table") represent databases which are read or written by entities. Dotted black arrows represent signaling exchanged between two entities, while plain black arrows indicate the flow of packets among entities.

VII. IP LAYER ENTITIES

User Plane principal entities are listed below:

The **Type of Protocol (ToP) Classifier**, which divides packets at the IP layer, according to their protocol.

The **Forwarding Module,** whose task is to look up the Routing Table to retrieve the "next hop IP address" for each packet to transmit. Then, this IP address has to be translated into an RTD L2 address by looking up another table, the ARP Table, where the association (IP address on the satellite link, L2 address) is contained. Finally, the packet is forwarded to the BNL along with the retrieved L2 address.

Control Plane principal entities are listed below:

The **RSVP Daemon**, whose role is to process RSVP signaling [2] and request reservation of resources for data flows that ask a differentiated QoS treatment.

IGMP, which performs Multicast related functions [6].

The **Routing Entity,** which updates the routing table.

ARP, which is called by the Forwarding Module when an IP address needs to be resolved into the corresponding L2 address. ARP entity behavior depends on the adopted ARP technique. In this regard, there are various alternatives for ARP operation in a satellite environment. For instance, the BMSS could adopt a centralized ARP entity whereby all the correspondences are stored in a proxy address server or a distributed ARP (in the fashion of Ethernet) where all BSATs or BHSs can reply to an address resolution query.

VIII. BNL LAYER ENTITIES

User Plane principal entities are listed below:

The **BNL QoS Management Entity**, which separates downstream traffic into IntServ flows or DiffServ classes on the basis of some fields in the datagrams' headers, as in [3]. When a Best Effort Service packet is detected (the Flow DB does not contain reservation state for it), if no channel towards the destination is available, this entity triggers a channel establishment in the RTD part. We use the more general term "channel" and not "connection" to take into account also the case of connectionless transfer.

TCP PEP, e.g. TCP spoofing, whose goal is to achieve a throughput enhancement for TCP connections [5][7].

The **Traffic Control**, whose main elements are a classifier, a set of policers, and a set of packet schedulers.

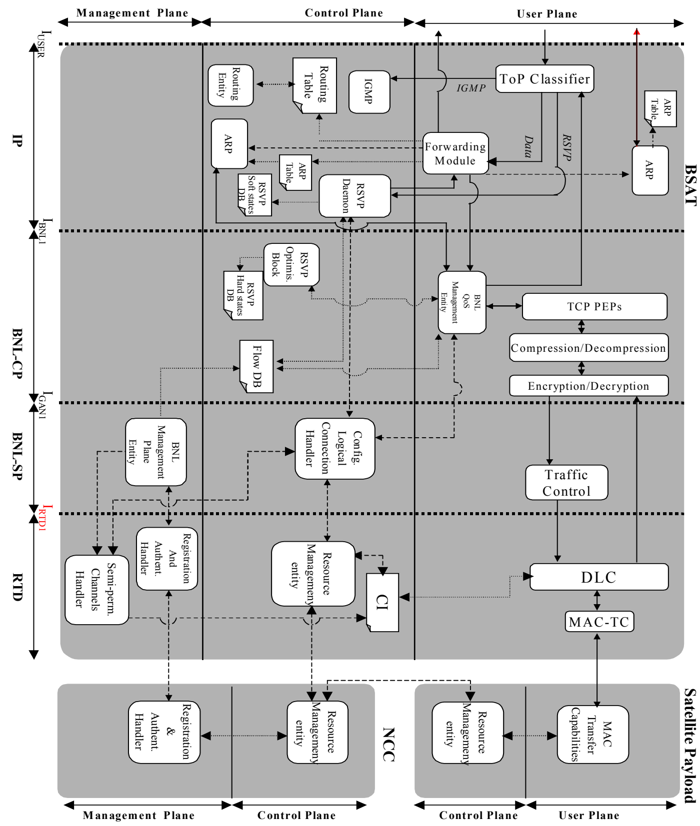

Fig. 3. BSAT Architectural scheme

The **Compression/Decompression Entity**, which performs header compression [5] for small PDUs on downstream flows, and then sends compressed packets along with their channel identifier (CI) to the Encryption/Decryption Entity. On upstream flows it makes the reverse function.

The **Encryption/Decryption Entity**, which encrypts/decrypts packets in the downstream/upstream link.

Control Plane principal entities are listed below:

The **Configurable Logical Connection Handler (CLCH),** which directly interfaces with the RTD entity (if any) that supervises resource management. This entity plays a key role in the BMSS as concerns RTI/RTD separability concept. In overview, this entity is placed at the boundary between RTD and RTI entities and talks with RTD Resource Management Entity translating BNL QoS parameters into the supported RTD specific parameters. The **Flow DB** is read and written by the RSVP Daemon, the BNL QoS Management Entity, and the BNL Management Plane Entity. It is also read by the Compression Entity

Management Plane principal entities are listed below:

The **BNL Management Plane Entity,** which accomplishes all management operations of BMSS complementing those which are carried out by the RTD system. In fact, as this entity directly talks with the RTD part, its tasks depend on the particular RTD system that is supported.

IX. RTD LAYERS ENTITIES

As concerns the RTD part, it should be noted that the descriptions made throughout the paper aimed at outlining the functional behavior from the point of view of the upper interface. In this regard, the main functional entities are:

The **Data Link Control (DLC) Entity**, whose main functions are packet segmentation and reassembly (SAR), multiplexing/demultiplexing, and forwarding;

The **Resource Management Entity** (**RME**), in charge of supervising switched transfer capabilities in those RTD system where they are supported.

The **Semi Permanent Channel Handler (SPCH),** which manages static pre-assigned Semi-Permanent Channels that can be modify only through management actions;

The **Medium Access Control (MAC) Entity,** which supervises access to radio channel;

The **Registration and Authentication** (**Reg&Auth**) **Entity**, that performs all those operations needed to register and authenticate a BSAT in the BMSS when it is turned on.

X. TRAFFIC CONTROL MODULE

The BMSS traffic control architecture is responsible for assuring Quality of Service (QoS) in the satellite link. This task is getting more and more important in modern telecommunication. The feasibility of supporting most demanding services is determined by the presence either of plenty of bandwidth or a powerful traffic control. In the case of satellite, where bandwidth is a particularly precious resource, a traffic control scheme is generally needed. The BMSS traffic control is implemented in the RTAL, which provides a RTI interface with the specific satellite platform. It is thought to support the five classes of service specific of the IntServ [1] and the Two-bit DiffServ [8] models, whose characteristics are summarized in Tab. 1. PS (Premium Service) and GS (Guaranteed Service) are suitable to support anelastic real-time traffic, while CLS (Controlled Load Service) and AS (Assured Service) can be used to achieve reasonably good performance with elastic traffic. BES (Best Effort Service) is a no guaranteed service for those applications with no precise commitments.

NAME	QoS MODEL	QUALITY DEGREE	DESCRIPTION
PS	Two-bit DiffServ	Highest	Null queuing delay, peak-rate-based allocation
GS	IntServ	High	Controlled queuing delay, guarantees on bandwidth
CLS	IntServ	Good	Congestion-free service, low packet delay and loss
AS	Two-bit DiffServ	Sufficient	Packet loss lower than in BES
BES	Any	Scarce	No guarantees

Tab. 1. Integrated IntServ and Two-bit DiffServ QoS classes

Traffic Control Simulation

This section illustrates statistics collected during a simulation of the BMSS traffic control architecture. They show how the five IntServ/DiffServ classes described above can be all efficiently supported. Performance of high quality traffic are particularly good and appears independent of the traffic load pertaining to low quality classes (good traffic isolation). Statistics are collected by means of an Opnet simulator of a BHS transmitting traffic into the satellite link under two different load conditions, i.e. injected traffic 100% and 110% of the total link capacity assigned to the node. Statistics were collected over a time window of 10 minutes in order to have small enough 95% confidence intervals. Fig. 4 shows the average queuing delay of packets to be transmitted in the satellite link. Queuing delays of the high quality traffic, i.e. PS, GS and CLS classes appears substantially insensitive to low quality traffic increase and remain limited to acceptable values. PS and GS classes appears suitable for supporting real-time traffic as they experience delays of the order of a few units of ms. In addition, the AS class guarantees significantly better performances with respect to simple BES. These values were obtained with a packet loss of the order of 1% for high-quality classes while AS class experienced a packet loss of one order of magnitude inferior to BES class.

XI. Conclusion

The challenge for the Next Generation satellite systems is to find an efficient integration in IP-centric Next Generation Telecommunication Networks. Research has delivered a number of proprietary solutions, which in the satellite field are hardly open to the public. This number is likely to increase in the next few years and in the long term. This work has proposed a general model for an optimized IP-oriented satellite architecture endowed with new features (such as QoS, support for multicast, security, mobility of terminals) in which a range of existing and future satellite technologies can be accommodated and exploited at the most by IP-based applications.

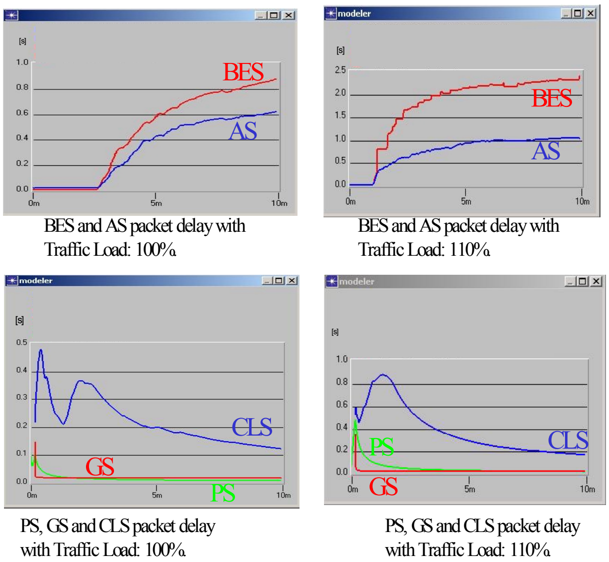

Fig. 4. PS, GS, CLS, AS and BES packet delay with different load conditions (100% and 110% of the total link capacity)

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