A TWO-WAY INTERACTIVE BROADBAND SATELLITE ARCHITECTURE TO BREAK THE DIGITAL DIVIDE BARRIER

Gabriele Boccolini, University of Pisa, Italy, gabriele.boccolini@iet.unipi.it
Marco Luise, University of Pisa, Italy
Benoit Garnier, Thales Alenia Space, Toulouse, France
Jean-Michel Merour, Thales Alenia Space, Toulouse, France
Alexandre Brunelle, EUTELSAT, Parigi, France
Sabino Titomanlio, MBI, Pisa, Italy
Vittoria Mignone, Centro Ricerche RAI, Torino, Italy
M.Angela Sasse, University College London, UK

Abstract

This paper presents a newly low-cost satellite architecture for the distribution of new broadband interactive TV-centric services to actual end-users in the home. The satellite connections provides the best and quickest solution to reduce the digital divide in less-favored areas, which has been considered as a major issue in the diffusion of broadband access. The platform employs DVB-S(2) and DVB-RCS technologies in the forward and the return link, respectively. The flexible framing structure of DVB-S2 and the adoption of the Adaptive Coding & Modulation (ACM) functionality allow an efficient exploitation of the satellite resource. The paper provides a description of the TV-Centric services, the required QoS and the relevant system architecture.

1. Introduction

Digital TV (DTV) is becoming increasingly available in almost every part of the world, allowing new technology and new applications to be introduced on a large scale. This will reshape the way consumers use DTV and other new media, such as interactive TV, Internet, mobile video and new combinations of those. Accessing and using these new multimedia services, whether via a computer, a mobile phone, or a TV Set Top Box (STB), will grow considerably, especially in major metropolises and most developed areas. Rural areas in well-developed countries and large areas with limited terrestrial network infrastructure in developing countries are still excluded from traditional access choices constituting an obstacle to harmonious continent-wide development.

Satellite-based telecom systems provide the best and quickest solution to reducing or eliminating the digital divide in less-favored areas to allow the diffusion of broadband access, owing to their wide geographical coverage and the speed and ease of deployment of terminal equipment. For satellite systems to fulfil this role, however, they must be efficient and cost effective, and capable of full inter-working with state-of-the-art terrestrial broadband networks.

This paper presents a two-way broadband satellite architecture developed in the framework of the UNIC (UNIversal satellite home Connection) project [1], sponsored within the 6th EU Research Programme Framework. The UNIC architecture provides TV-Centric triple play services to actual end-users in the home employing DVB-S(2) and DVB-RCS technologies [2,3] in the forward and the return link, respectively, together with a newly low-cost defined architecture for the distribution of connectivity to end-users.

The flexible framing structure of DVB-S2 and the adoption of the ACM functionality allow optimizing the transmission parameters for each individual user on a frame-by-frame basis, dependant on path conditions and required QoS, under closed-loop control via the satellite return channel. The result is an efficient exploitation of the satellite resources and even greater gain of DVB-S2 over DVB-S for point-to point applications.

The main application scenario of the UNIC system is a remote village not served by terrestrial broadband infrastructures (i.e. ADSL, WiMax). This platform is therefore designed to provide (i) broadband connectivity to the homes, via a bi-directional Collective Satellite Gateway (CSG) located in a building or a village city hall (e.g. serving a group of houses, a village, a large multi-storey building), and (ii) conventional TV/HDTV services via Direct-to-Home (DTH) reception. The user STB, allowing seamless access to the various services independently from their origin/transport infrastructure, is an hybrid DVB and IP box connected to the CSG through a wired (Ethernet LAN) or wireless

(WiFi/WiMax LAN) local broadband network (for interactive IP-based services) and to the DTH receiving antenna through the home cable network (for TV/HDTV services).
The UNIC system provides a set of primary services such as Internet, interactive TV, IPTV, HDTV, VOIP and videoconference services together with another set of innovative services such as surveillance, monitoring, tourism information, distance learning and home-based care services that will reshape the way consumers use DTV.
The system two-way platform fully support the IP and TCP/IP protocols, resulting in an optimisation of the required satellite bandwidth. A reduction in the amount of bandwidth needed lowers network costs and allows for greater profitability of new services.
The first step of the project was to imagine a contour of ser-vices towards users of existing satellite TV services who have no access to alternative services (PC access, web access, email, video conferencing, music download). Afterwards, we identified which services were more suitable and viable when carried over new satellite technology. The result of this study is a list of potential services listed in the Section 2.
Once the services were defined, the technology adaptation needed to be prototyped to enable their delivery. This required a thorough evaluation of the key parameters impacting the quality of each service - bandwidth, packet loss, delay and jitter - alongside a study of the likely usage across a population to estimate the burstiness of the underlying video traffic. This analysis will be the subject of section 3. In section 4 we will describe the overall architecture of the system, and we will draw some conclusions in Section 5.

2. TV-Centric Services

In this section we will first list a set of primary services constituting the must of UNIC, that are commonly gathered under the term of Triple Play services. These are mainly entertainment services using the TV set as a universal gateway for consumers at home. They all present some differences compared to the usual Triple Play services offered today. Another set of services is further defined to exploit the possibilities of UNIC to provide new original features to consumer or to extend them to business users.
The list of defined services is not exhaustive neither it is supposed to be supported entirely by the UNIC project. This list is solely intended to provide a general overview of the possibilities of UNIC in the context of TV evolution.

A. *Real Triple Play*

Beyond Internet services: *Web2TV, Email2TV, Chat2TV, Music Download/Playback, Online Gaming, Home on Demand Gaming, Extreme Online Role-Playing Game (XORGS) Audience, Cyber-Gaming.* Internet TV-centric services are mostly intended for people who do not own computers in order to make the World Wide Web available to everyone.

Beyond TV services: *SD/HD TV, Personal TV, Interactive TV, Interactive TV return Channel, Personal Video Recording (PVR), Time Shifting (TS), Video on Demand (VoD), Electronic Program Guide (EPG), Mosaic*. Several of these are already delivered by terrestrial and satellite Digital TV providers using the current PSTN return channel for interactive services. Exploiting the satellite return channel combined with the DVB-S2 technology will allow UNIC to be an attractive alternative.

Beyond phone services: *Phone2TV, Video Conferencing.* The TV-Centric structure will ensure that any person with a TV set can potentially communicate with voice and/or video with one or more other distant persons. These services already exist on terrestrial broadband but require a computer, a web-cam and adequate video conferencing software. Having a TV-Centric video conferencing service available to any person owning a TV would have a great impact on the business con-text, considering that it provides a turnkey solution for video conferencing.

B. *More Services*

Surveillance and monitoring services: *Home/Office Surveillance/Automation, Weather Monitoring, Crop Monitoring & Management.* These services are designed mainly for industrial applications in developed area and to meet local governments’ needs in rural areas in developing world.

Tourism services: *Interactive Travel Channel, Virtual Cultural Visit (VCV), Real Estate Timeshare Information, Nightlife Events Information, Weather Forecast*. It will be possible to access to tourism information in remote areas lacking Internet connection.

Other services: *Bringing Courses Into Home, TV All Together, Live Announcement, Assisted Living, TV Health Centre.* UNIC can give a large contribution to the continuing trend of distance learning and home-based care services reshaping the way consumers use Digital TV.

3. TV-Centric QoS

This section focuses on the performance requirements of services from the user perspective. The performance requirements were obtained similarly to ITU G.1010 [4] to take into account all aspects of a service as it can be experienced by the user. These requirements are network-agnostic and focus on user-perceivable effects.
We exploited the QoS criteria commonly used for IP data communication services to define the QoS requirements for the particular services.
QoS criteria for IP data communication services are based on the definition of parameters that allow specification and assessment of the performance of speed, accuracy, dependability and availability of the IP data communication services. In the process of IP packet transfer, the following event can take place: successful transmission, loss and error. Based on such outcomes, the following transfer parameters can be defined:

- Transfer Delay, mean and variation (jitter): defined for all successful and erroneous packets. Delay variation on a satellite link mainly occurs due to processing and queuing.
- Packet Error Rate (PER): ratio of number of corrupted packets to total number of packets transferred.
- Packet Loss Rate (PLR): ratio of number of packets lost to total number of packets transferred. Packet loss occurs due to congestion, link outages, and error conditions.
- Throughput - peak and mean: total number of IP packets successfully transferred during a specified time interval divided by the time interval duration (peak and mean values).

We investigated the basic services establishing a set of recommended values for each transfer parameters. Table I-II show QoS requirements for some of the most relevant applications provided by the system. These requirements must be fulfilled to achieve sufficient service quality. We use these applications as building blocks for the more advanced services outlined in Section 2. For instance, the Video Conference service requirement is the combination of Conversational voice (code A1) and Videophone (code A2) application requirements.

4. System Design

The UNIC System Platform is composed of four segments:

- User /Home Service Segment
- Collective Service Segment
- Transport Media Segment
- Ground Service Segment

4.1. User/Home Service Segment

The User/Home Service Segment (USS) comprises the components/functions that will allow home users to access triple-play services on traditional TV Set and commercial smart phone/PDA. The User/Home Segment comprises the STB that will be connected via IP (wireless or wired local network) to the Gateway. The Gateway can normally consist of the avail-able Collective Gateway but can also consist of a Gateway installed at home, Home Gateway (HGW).
The user is intended as a non technical single in-home user and accesses the normal broadcasted programs and interactive services mainly from the television equipment connected to the STB. The user can also provide his own multimedia content via mobile phone or PC to a central collection point.

TABLE I
PERFORMANCE TARGETS FOR AUDIO AND VIDEO APPLICATIONS

Code	Application	Typical data rates	Key performance parameters and target values			
			One-way delay	Delay variation	Information loss	Other
A1	Conversational voice	4-64 kbps	<150 ms preferred; <400ms limit	< 1 ms	< 3% PLR	
A2	Voice messaging	4-32 kbps	< 1 s for playback; < 2s for record	< 1 ms	< 3% PLR	
A3	High quality streaming audio	16-128 kbps	< 10 s	<< 1 ms	< 1% PLR	
A4	SD TV audio MPEG-2	256 kbps	<10s	<< 1 ms	< 1% PLR	
A5	Dolby 5.1 surround sound	N/A	<10s	<< 1 ms	< 1% PLR	
A6	SD TV audio MPEG4	66 kbps	<10s	<< 1 ms	< 1% PLR	
V1	Videophone	16-384 kbps	< 150 ms preferred; <400ms limit	N/A	< 1% PLR	Lip-synch:<80ms
V2	Video obs. or announcement	16-384 kbps	< 10 s	N/A	< 1% PLR	
V3	IP TV	512 kbps	< 10s	< 1 ms	< 1% PLR	Lip-synch:<80ms
V4	SD TV (MPEG2)	2-3 Mbps	< 10s	< 1 ms	< 1% PLR	Lip-synch:<80ms
V5	HD TV (MPEG4)	10-12 Mbps	< 10s	< 1 ms	N/A	Lip-synch:<80ms
V6	SD TV MPEG4	1-2 Mbps	< 10s	< 1 ms	N/A	Lip-synch:<80ms
V7	Very low frame rate, pictures	16 kbps	< 10s	< 1s	N/A	

TABLE II
PERFORMANCE TARGETS FOR DATA APPLICATIONS

Code	Application	Typical amount of data	Key performance parameters and target values	
			One-way delay (Note)	Information loss
D1	Web-browsing- HTML	~ 10KB	Preferred < 2s/page; Acceptable < 4s/page	Zero
D2	Bulk data transfer/retrieval	10KB - 10MB	Preferred < 15s; Acceptable < 60s	Zero
D3	Transaction services - high priority	< 10KB	Preferred < 2s; Acceptable < 4s	Zero
D4	Command/control	~ 1KB	< 250 ms	Zero
D5	Still image	< 100KB	Preferred < 15s Acceptable < 60s	Zero
D6-1	Interactive games – First-Person Shooter	Up: 16kbps Down: 16kbps	< 200 ms	Zero
D6-2	Real-Time Strategy video game	Up: 8kbps Down: 8kbps	< 200 - 500 ms	Zero
D6-3	Multiplayer Online Role-Playing Game	< 1KB	< 100 ms - 1s	Zero
D7	Telnet	< 1KB	< 200 ms	Zero
D8	E-mail (server access)	< 10KB	Preferred < 2s Acceptable < 4s	Zero
D9	E-mail (server to server transfer)	< 10KB	Can be several minutes	Zero
D10	Fax ("real-time")	~ 10KB	< 30s/page	$<10^{-6}$ BER
D11	Fax (store & forward)	~ 10KB	Can be several minutes	$<10^{-6}$ BER
D12	Low priority transactions	< 10KB	< 30s	Zero
D13	Usenet	Can be 1MB or more	Can be several minutes	Zero

The STB is defined as an intelligent network interface device located at the consumer premises, which provides the means for a residential user to access the services delivered to the home and possibly to access the different services offered by the various smart devices located within home. Essentially the STB device provides the necessary connectivity features to enable the consumer to exploit the advantages of a networked home. This device can for example perform bridging/routing functions and address translation between external satellite network and the internal home network. In particular the STB can support functions like Internet connection sharing and Internet access, In-home file sharing, In-home Wireless LAN connectivity, VPN connectivity to work place, IP telephony, IP VoD, In-home audio and video streaming, etc.

The STB is responsible for dealing with users requests through the remote control (additional user inputs to be considered like webcam, microphone, etc.). Requests are handled locally or transmitted to the Gateway if a connection to the outside world is required. The STB is also responsible for video and audio output as well as application interfaces rendering to television. The video/audio output may come from local content stored on the STB, from user generated content (web-cam, PDA) or from the outside network (Internet).

4.2. Collective Service Segment

The Collective Service Segment (CSS) contains all those components/functions providing services to a community of users (i.e., the residents of a multi-storey building or the in-habitants of a small country village) connected to a bi-directional satellite terminal. Since the satellite media is particularly suitable for multi-casting applications, local storage is a key function of the CSS to allow high quality multimedia services and optimum use of the satellite frequency resources. In case of unicasting, the satellite segment provides ACM functionalities (using the DVB-S2 standard) in order to maximize the satellite capacity throughput .

The Collective Gateway (CG) is the core of the CSS. The CG is the local unit of the platform providing a number of functions available to all the users connected to it. Components of the CG can be described as follows:

The Captive Portal (CP) is the subsystem that permits users to access to the built-in TV-Centric Services. Each request coming from the final users is mediated by this portal. The system is accessed using a standard web interface, optimized for STBs and user devices, which lists all available services. Every service request is redirected to the Collective Service Unit (CSU) which processes it and verifies that QoS rules are matched and satisfied.

The Local VoIP Gateway provides VoIP services to the users. It is interconnected to the centralized VoIP Gateway in the Service Operation Centre (SOC) and provides access to the telephone network using this peer system. The VoIP system hierarchy based on multiple local gateways connected to a master unit allows the system to be very scalable and to handle locally calls between users connected to the same CG, with no need for satellite bandwidth.

As per the VoIP subsystem also for web content browsing a two level architecture has been chosen. This means that when a user requests a web content the request is automatically redirected to the Local Web Server. If the page is already cached by this system (e.g. already requested previously and not yet expired) it is returned to the requestor with no occupation of the satellite link. If the page is not stored yet in the local cache the request is routed to the centralized web proxy-cache and then, if needed to the Internet.

The CSU is the real core of the CG. It processes information coming from several sources (i.e. requests from the captive portal, information from the SOC, QoS requests, etc.) and serves most of the subsystems in the gateway.

The Ethernet and Wireless Local Units interconnect the CG to STBs and clients. They also provides status and management information (e.g. SNMP).

The Local QoS Manager is in charge of deciding the QoS policies to be applied for each client and for the whole CG. It is interconnected with the QoS-to-ACM Controller which is responsible for remapping QoS requirements in ACM messages to be sent to the peer system (QoS-to-ACM Actuator) in the Service Operation Centre. QoS information at application level are processed by the Local QoS Manager that can decide to generate ACM messages. The messages are prepared and de-livered by the QoS-to-ACM Controller.

The Satellite Transport Media Channel component acts as an interface between the satellite network and the CG. This system is used to route traffic in both directions and to control the availability of the satellite link. There is also a Terrestrial Return Link component which is an optional backup solution for the interconnection of the CG to the Ground Service Segment in case of unavailability of the satellite link. It requires a backup media (e.g. PSTN, xDSL).

The Multicast Content Delivery Client (with Local Storage) subsystem receives contents distributed in multicast, stores them on a local storage area and makes them available to the STBs and the client devices.

4.3. Transport Media Segment

The Transport Media Segment (TMS) provides a communication network that supports multimedia services over GEO bent pipe satellites. It includes ground subsystems (hub, teleport for satellite), communication infrastructure and local terminals. The TMS is designed to complement the direct satellite broadcast (one-way) audio and video transmission channel with a bidirectional IP based access system.

The satellite transport network comprises one Gateway and a large number of Satellite Terminals (ST) connected with the CSS or the HGW. It supports star links between the Gateway and the ST, but also ST to ST connectivity through the Gate-way.

The Gateway is the central component of the network. It offers a connection to the UNIC platform – and wherefrom external networks – through its IP router. The Gateway handles the traffic between the

platform/external networks and the STs and manages all access services. It provides a powerful radio resource management, which allows efficient utilization of the satellite capacity with circuit and packet types of traffic.
The TMS is described here in a layer based approach. The access layers are divided into the following two links: the forward link, which provides connectivity from the gateway to the STs, based on the DVB-S(2) standards, and the return link, which provides an MF-TDMA access scheme offering cost-effective sharing for the return bandwidth between the STs, based on the DVB-RCS standard.
The access layers are sub-divided into the physical layer (modulation, bursts), the layer 2 transport layer (ATM or Multiprotocol/Generic Stream Encapsulation) and the Medium Access Control (MAC) sub layer. The latter handles the map-ping and scheduling of higher layer flows onto layer 2 trans-port means and it is an important part of the end-to-end QoS enforcement.
At the transport layer, the segment also supports a specific acceleration scheme in order to mitigate the “high delay x bandwidth” adverse effect of the satellite transmission channel on TCP connections.
Two options have been selected combining ACM and QoS to ensure that service needs are fulfilled in real time by the access transport capabilities: 1) A layered approach, in which ACM is restricted to physical and MAC mechanisms, providing “ACM-ized’ transport capabilities on which network level CoS classes are mapped; 2) A inter-working approach, in which ACM is tightly integrated to the QoS provision mechanism and involve all UNIC system layers, including those external to the TMS (external application layer integration).
From the segment point of view, the main differences between the two options are the use of an advanced ACM modulation and coding stream processing MAC block in the first option, and the provision of external ACM control interfaces and an ACM function in the gateway router block in the second option.

4.4. Ground Service Segment

The Ground Service Segment (GSS) contains the:

- Service Operation Center
- Multicast Content Delivery platform
- Integrated Value added Service platform.

The GSS allows:

1) Independence from the actual service providers making the UNIC platform ready to interoperate with different “Existing Service Providers”, such as mobile operators, IPTV broad-caster, etc.

2) Central provisioning and access of basic services, making it easy to account and log services and to monitor actual performances.

3) Integrated QoS Management specifically designed to optimize the perceived QoS in the collective scenario, and possibly work in conjunction with the QoS management module at level of TMS.

4) Easy integration of Value-Added Services, such as Push VoD and User-Generated Content or other service platform from external actors.

The Service Operation Centre (SOC) provides an independent access to all the available transport media as well as gate-way to provide basic services such as SMS/MMS, Email, Internet Access, VoIP Gateway.
The Multicast Content Delivery platform is the core of the content distribution system. It is a hardware/software system designed to handle robust and secure multicast content distribution with no return channel. It is based on a Multicast Delivery Framework (MDF), that is a general framework for easy, robust, optimized and secure multicast file delivery and has two main components: MDF Server and MDF Client. The MDF Server has the main role of file pushing through the one-way multicast channel. In order to allow an MDF client to receive the right and expected file other synchronization information are sent, called Electronic Service Guide (ESG). MDF is optimized with full bandwidth control and group management to send the same content to more than one user, but not all the user.
The Integrated Value Added Service platform allows the following processes to be applied to the multimedia content: acquisition, storage, metadata provision, transcoding and Digital Right Management.

4.5. External Actors

The integration of External Actors (EA) will allow the interchange of data outside the described platform to the external world. The EA are PSTN/VoIP Telephony Operator/Network, Mobile Voice/SMS/MMS Operator, Internet Service Provider, IPTV Broadcaster Service Platform.

5. Conclusions and Perspectives

The above paper gives a description of the interactive bidirectional satellite architecture being developed in the UNIC project. Prototype and platform assembly phase is running throughout 2007, following a stepped scenarios approach. First the delivery of basic IPTV services over satellite is to be validated. Then, additional services (push and forward solutions, content delivery) will be added. In parallel, the development of an hybrid STB is undertaken. The STB will be capable to receive IP channels as well as traditional satellite broadcast. Finally, more interactive service will be tried for demonstration. At the end of the project, it is expected that the proof of concept platform will show the potential of the TV-centric satellite approach, using efficient standards, and leveraging on terrestrial IP solutions, to bring to TV users in remote areas an effective access into the digital world.

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