Automating Production of Cross Media Content for Multi-channel Distribution

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DE4.8.1.3
Content Distribution via Satellite Data Broadcast, update of DE4.8.1.2

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Abstract:
The present document is an update of the previous DE4.8.1/DE4.8.1.2 on content distribution via satellite data broadcast. It includes report on the activities related to the research on technologies that enable the application model of content distribution via satellite to both PC and STB, and streaming to STB.

Keyword List:
Content Distribution, Satellite, Broadcast, PC, STB

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1 Executive Summary and Report Scope

Market and end-users are pressing content industry to reduce prices. This is presently the only solution to setup viable and sustainable business activities with e-content. Production costs have to be drastically reduced while maintaining product quality. Content providers, aggregators and distributors need innovative instruments to increase efficiency. A solution is automating, accelerating and restructuring the production process to make it faster and cheaper.

The goals will be reached by: (i) accelerating and reducing costs for content production with artificial intelligence algorithms for content composition, formatting and workflow, (ii) reducing distribution and aggregation costs, increasing accessibility, with a P2P platform at B2B level integrating content management systems and workflows, (iii) providing algorithms and tools for innovative and flexible Digital Rights Management, exploiting MPEG-21 and overcoming its limits, supporting several business and transactions models.

AXMEDIS consortium (producers, aggregators, distributors and researcher) create the AXMEDIS framework with innovative methods and tools to speed up and optimise content production and distribution, for production-on-demand. The content model and manipulation will exploit and expand MPEG-4, MPEG-7 and MPEG-21 and others real and de-facto standards.

AXMEDIS will realise demonstrators, validated by means of real activities with end-user by leading distributor partners: (i) tools for content production and B2B distribution; (ii) content production and distribution for i-TV-PC, PC, kiosks, mobiles, PDAs. The most relevant result will be to transform the demonstrators into sustainable business models for products and services during the last project year.

The present document is the third and final deliverable concerning the WP4.8 on Content Distribution via Satellite Data Broadcast. Its purpose is to report the activities related to the research on technologies that enable the application models based on a content distribution via satellite data broadcast and described in section 18.2 of DE2.1.1a (User Requirements and use cases).

The objective of these research activities is to study, explore and define new delivery models based on content distribution in broadcast, i.e. to a large number of users with a single transmission; more specifically, the chosen model is the satellite multicast via satellite. Another objective is to study consumer models based on client-side content composition. In particular, the research aims to define and verify algorithms and methods able to produce personalised audio-visual programs and media on demand services by aggregating content, from different sources, directly on the client terminal.

The general description and research specification provided in this section is also intended to cover research activities related to the demonstrator task of WP 9.3.

All research activities will refer to the guidelines stated in DE3.1.1 (Guidelines and Specifications of Research).

1.1 Modified sections

This section summarizes main changes in this deliverable with respect to the previous DE4.8.1.2 “Content Distribution via satellite data broadcast, the push optimisation and the on demand problem, first update” (M24).

Added Section 4

According to the new directions of the project, and specific to this WP, section 4 has been introduced: the section reflects the fact that the target of the distribution includes now, besides the traditional PC-based clients, also the Set-Top Boxes.

STB has been added to the list of devices supporting the AXMEDIS model, and they can act as PVR – when provided of a hard-disk to store the content received in push via satellite, for further fruition – or for streaming of the content (real time fruition).

2 Description of last year task

T4.8.1 Content Distribution towards both Set Top Box and PC-based clients (new task, started at M25) -- MBI responsible – planned to be completed for M36.

The present task is related to the research activities of the "Distribution mechanism via satellite data broadcast" application model, consideing both PC and STB based clients. The objective is to enforce the AXMEDIS model into STB and PCs. They are not simple STB, they are evoluted Personal Video Recorder, PVR, with HD for storing data, and guide for selecting programmes to be stored. In this sense they are much more similar to a PC than traditional STB as decoders.

The main aim of this task is to study and enforce the AXMEDIS technology into a STB that has to able to receive multimedia contents in the AXMEDIS format but also MPEG4 and MPEG-21 format from a satellite network and to provide them to the final users through a normal television set. The future STBs will be able to get data from a DVB-S connection, using the server side infrastructure of the EUTELSAT OPENSKY™ Multimedia Platform.

The contents that will be distributed are of two types:

- real time audio/video streams
- video/media on demand contents

These two types of content cover the two main applications targeted by AXMEDIS:

i. access to streamed TV/radio (compressed with advanced technologies MPEG4 based);
ii. access to Media-On-Demand content.

The hardware components will be purchased from external manufacturers. Equipment acquired during the project. The work for producing the AXMEDIS based STB will be supported by MBI, TEO, ELION and KTU providing software components for STBs included into the AXMEDIS framework as core technology in source code. The work in task will be supported by the DSI work on AXOM and UPC work on PMS client.

The involved actions can be summarised as follows (suggested milestones are reported in brackets):

- M30: Report on existing standard multicast protocols like FLUTE, Multicast Dissemination Protocol, in order to reach standard levels in metadata used in OPENSKY
- M36: First version of integrated AXMEDIS software into the PC and STB including AXOM and PMS, ready for the demonstration performed in WP9
- M36: Final version of integrated AXMEDIS software into the STB including AXOM and PMS, running in the demonstrator of WP9

3 The distribution mechanisms via Satellite Data Broadcast

3.1 System Analysis and State of the Art

One of the main goals of the task T4.8.1 is the analysis of the problems related to the distribution of content in pull-push via satellite data broadcast by considering B2B and B2C aspects, and its optimisation, with the aim of reducing the costs for the distributors and the price for the consumers.

The content distribution in broadcast for the B2B support of the AXMEDIS content has to be regarded as way to accelerate the distribution process in the respect of the cost for the users. Users are not intended only as final users B2C, but also B2B users: for example, a possible application is the distribution of content in push towards the kiosks, to renovate their libraires and databases automatically, with weekly or monthly updates.

Multicast File Delivery systems have captured the attention of different players of the Broadcast/Broadband/Telecom world because these systems are able to diffuse simultaneously content to multiple users, avoiding sending multiple copies of the same content to each user. This feature is particularly relevant in the scenario of the content distribution direct-to-mobile (DVB-H).

Since the Multicast is not fully supported by the terrestrial networks (not uniform development of the MBONE), almost all implementations of this technology use the Satellite Networks, where the Multicast Protocol has been easily implemented.
However, even if a lot of papers have been published on this domain, there are still several open topics for further improvement and research.
In the definition of a Multicast File Delivery System there are different points to be taken into account:

- Reliability of transmission
- Optimisation of Bandwidth Allocation
- Reducing the use of point-to-point connections (pull operations)

EUTELSAT is responsible for the development of a Multicast File Delivery solution called Satellite Data Broadcast (SDB). Deriving from this position, EUTELSAT analyses constantly several existing (and proprietary) systems in order to compare its system with concurrent ones.

During the study and design phase of the Satellite Data Broadcast (SDB) in EUTELSAT, some existing (and proprietary) systems were analysed, in order to identify the main features needed to have a well running service.
The analysis of these systems are reported in the following subsections, and a comparison table resuming the results is presented at (3.1.7).

3.1.1 Fazzt™ Digital Delivery System

It is a system developed by KenCast™ in order to implement a satellite broadcast system, which can deliver large files directly to authorised terminals at thousands of sites. Fazzt™ reliably delivers big amount of data at speeds exceeding 24 Mbps using advanced error-correction, compression, and validation software in the transmitting PC and in each receiving PC.
KenCast's Fazzt Forward Error Correction (Fazzt FEC™) algorithms assure a good level of broadcast reliability, even where no return links are available, and even in rainy weather.
In the system is possible to find all standard modules of a system Push, anyway, the user has to communicate with the backend for different reason, making the system not really suitable for the scenario without return link.

3.1.1.1 Core Technologies

- **Fazzt Forward Error Correction*.** Allows reliable one-way transmissions by using a proprietary mathematical algorithm to reconstruct damaged transmissions when they are received. This works on any file type, even for extended outages. Fazzt FEC® technology also works on streams of live data. Send the data once, and only once. No costly retransmissions, power boosts, or return link are required. Fazzt will save you time and money by ensuring that your data arrives intact despite adverse conditions that inevitably arise.
- **Fazzt File Validation*.** Verifies that the file as reconstructed is identical to the file as sent.
- **Compression.** Compress files before sending to decrease needed bandwidth. Compression can be configured universally or on a per-transmission basis.
- **Optimised retransmission*.** If a return link is available and a file arrives at one or more receive sites too damaged to be reconstructed, Fazzt will optimise retransmission of the missing data.

3.1.1.2 Core Features

- **Content database.** Fazzt maintains an internal database of content, along with meta-data information about the content.
- **Hot Folders.** Directories can be configured to wait for files to be dropped in them, and immediately transmit the files over the satellite network with given transmission parameters.
- **Dynamic channels.** Multiple channels of content, either files or streams or a combination of both, can be multicast. The client can filter and tune among them. Channels can be permanent or temporary, set up and taken down on the fly.
- **Distribution Center for Content on Demand.** Clients can directly subscribe to channels or streams available at the server, or order content through a searchable catalogue.
- **Flow control.** Integrated opportunistic bandwidth support with IP encapsulators allows Fazzt to make use of the maximum available bandwidth.
- **Multiplexing.** Send multiple files concurrently; high priority files are sent first.
- **Transmission queue management.** Multiple scheduling and queueing algorithm options allow added control over transmission priority.
- **Selective transmission.** Send files only to selected receive sites, if desired. Define groups of receive sites, or groups of groups, allow publishers to define their own groups, or tap into an existing user database using ODBC. Fazzt's addressing scheme imposes no limit on the number of receive sites.
- **Selective reception.** Remote users can choose which categories of files to receive using filters, or select files from a carousel. Carousels and category lists can be broadcast to all receive sites and updated.
- **Mirroring.** Fazzt can easily mirror FTP sites, web sites, or data banks.
- **Packaging.** The Packager utility wraps multiple files into a package. This package can later be transmitted, and will be unpacked into the original directory tree upon arrival at the receive site. A script can be included which will run automatically at the receive site, processing the package in customisable ways. The packager includes a Windows graphical user interface, a console interface, dozens of options and a wide range of automation features. A UNIX version is also available.
- **Fazzt Digital RecorderTM.** Allows scheduled or spontaneous recording of incoming streams at the client, for later viewing or playback.
- **Backhaul.** Transfer files over TCP/IP from one Fazzt machine to another using ISDN, Internet, or modems.
- **Logging.** Extensive, flexible logging functionality allows for easy tracking and reporting of system operations.

3.1.1.3 Automation

- **Scripting Engine.** Automate common maintenance tasks, build simple interactive applications, and easily integrate Fazzt with your existing system using scripts. Scripts can be run on any Fazzt PC and scheduled for any recurrence pattern. Fazzt machines can run scripts on other Fazzt machines, easing system integration and simplifying maintenance. Since scripting is integrated system-wide at a low level, every system function can be controlled through scripting.
- **Scheduler.** Schedule files or packages to be sent in the future. The graphical user interface allows an extensive variety of recurring transmission schedules to be programmed. Scripts can also be scheduled for execution. Scheduling can be configured through the user interface or through scripts.

3.1.1.4 Integration Features

- **Interactive Internet applications.** Easily build messaging systems, video on demand, and files on demand systems, which can be controlled through any web browser, anywhere.
- **Centralised management.** Receive sites can be controlled by the uplink site. The Server can run scripts at receive sites for configuration or maintenance, or upgrade Client software by simply sending one file.
- **Distributed Control.** Control Fazzt from the server, publisher, client, or any web browser.

- **Email support.** Fazzt supports the POP3 and SMTP standards, which allow the system to, for example, forward email to client computers, retrieve instructions via email, send emails upon receipt of files, or email a pager if an error occurs.
- **Open database support.** Fazzt can integrate with any enterprise database system through ODBC. Simple Fazzt scripts can make arbitrary SQL calls, receiving instructions through a database or reporting back to one.
- **FTP, SNMP, and CGI support.** Configure Fazzt to download files from any operating system with FTP, and transmit them over satellite. Use Fazzt scripts as CGI processes, or configure Fazzt to send SNMP traps.
- **Compatibility.** Fazzt software runs on Red Hat Linux and all 32-bit Windows platforms, including Windows 95, Windows 98, Windows ME, Windows NT, Windows 2000, Windows XP, and Windows Server 2003. Fazzt Client software is also available for Windows CE, other Linux distributions, FreeBSD, UnixWare, and Apple MAC OSX. Embedded support for internet standards ensures that files can be downloaded for transmission from any computer on the internet, and routed to any machine upon remote arrival. Fazzt supports IP Multicast, RS-422, and RS-232 standards.
- **Mobility.** Fazzt clients can be PCs and/or handheld PDAs, with much of the capability similar across the network.
- **Security.** Fazzt's built-in authentication server provides security for Fazzt Systems configured with interactive internet capabilities and will interoperate with any web server. Fazzt's open architecture allows for easy integration with third-party encryption products.
- **SDK.** Fazzt's Software Development Kit and Developer Web Tools provide assistance to the developer for integrating Fazzt with other applications.

3.1.1.5 System Requirements

At the uplink site, Fazzt® software runs on Windows NT/2000/XP/2003 and Red Hat Linux. At the receive sites, the Fazzt Standard Client software runs on Windows 95/98/ME/NT/2000/XP/2003, Linux, FreeBSD, UnixWare, and Apple MAC OSX. The PDA Client runs on Windows CE. The Fazzt Enterprise Client runs on Windows NT/2000/XP/2003 and Red Hat Linux. The list of supported platforms is constantly growing; contact KenCast if you need information about an unlisted platform. Both the server and the client PCs are generally provided by the purchaser.

For IP Multicast systems, a standard ethernet card can connect the PC to the receiver or transmitter. For RS-422 systems, KenCast provides a high-speed ISA or PCI card to connect the PC to the receiver or transmitter. The software operates the same in either case. You should check the specifications of the satellite transmitter and satellite receiver you wish to use before ordering. With standards-compliant transmitter and receivers, Fazzt will work on all digital satellite circuits -- in Ku, C, Ka, and other spectrum bands.

3.1.1.6 Basic Technical Specifications

- **Protocols**
  IP Multicast, UDP/IP, TCP/IP (Fazzt software only, uses standard network interfaces)
  RS-232 (Fazzt software only, uses standard serial ports)
  RS-422/HDLC (Fazzt software, Fazzt card required)
- **High Speed Serial cards:** (RS-422 only)
  ISA
  PCI
- **Operating Systems**
  Fazzt Server: Windows NT/2000/XP/2003; Red Hat Linux
  Fazzt Publisher: Windows 95/98/ME/NT/2000/XP/2003
  Fazzt Standard Client (Remote Station): Windows 95/98/ME/NT/2000/XP/2003, Linux, FreeBSD, UnixWare, Apple OSX

Fazzt Enterprise Client: Windows NT/2000/XP/2003, Red Hat Linux Fazzt PDA Client: Windows CE 4.2 or later (e.g., Pocket PC 2003, Pocket PC 2003 Second Edition)

- **Bandwidth**
  IP: Limited only by hardware, over 90 Mbps on typical machines, over 300 Mbps on high-end equipment
  RS-422 ISA: Up to 8Mbps
  RS-422 PCI: Up to 20 Mbps

3.1.2 SkyStream zBand™

zBand™ is Content Distribution and Management Software developed by SkyStream. It is an IP based content delivery platform that can be used independently of SkyStream products.

The Server allows creating and managing content and to schedule the transmission of the content to Clients. The transmission is done following the PGM (Internet Draft: Pragmatic General Multicast) Industry standard. Furthermore, PGM allows the reliable delivery of multicast traffic by means of FEC (Forward Error Correction) insertion and Negative Acknowledgements (NACKs) to the server. In order to avoid the “NACKs implosion” phenomena (Clients overloading the server with thousand of requests of the same packet) an architecture based on “Network Elements” (NE) is used. NE serves a population of clients; they receive and store the content that is being transmitted by the server (sliding window). Then, NE receives NACKs from clients, and acknowledges its reception by multicasting to all clients a Negative Acknowledgement Confirmation (NCFs). It could be that the packet lost by the Client is present on the memory (due to previous requests) of the NE; the NE shall forward the packet to the client. Otherwise, if the packets is not present on the NE; the NE shall forward a “request to resend” to the server, filtering out eventual duplicate NACKs coming from other Clients.

3.1.2.1 zBand Applications

The zBand Content Delivery Platform from SkyStream Networks integrates Live IPTV with PUSH-based Media on Demand (MOD). zBand's client-server software architecture offers the security, control, reliability and cost-effectiveness needed to deploy IPTV and data dissemination services.

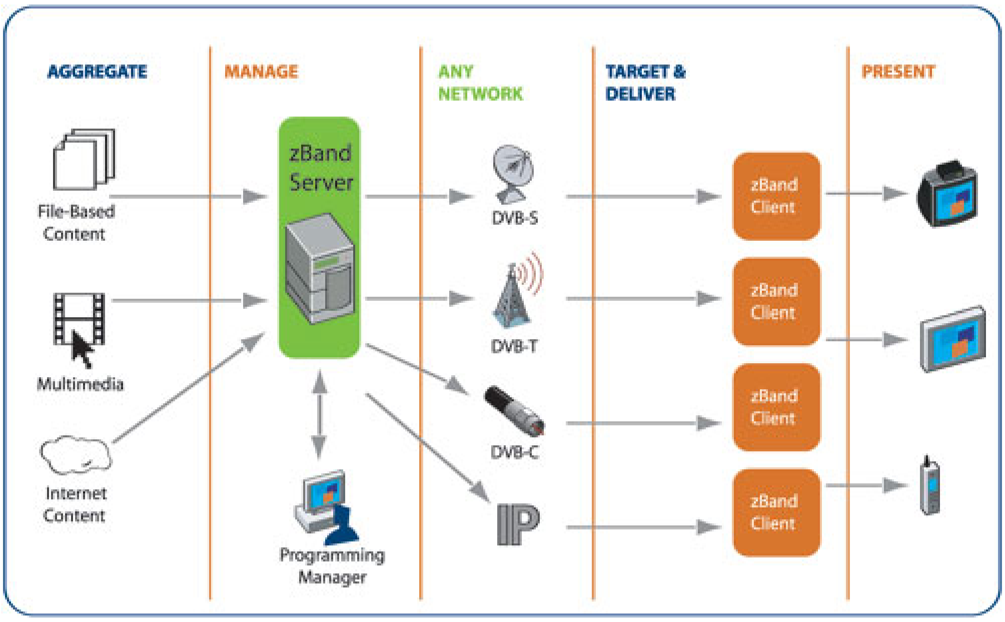
- **Media on Demand - Security to Combat Signal Theft**

As service providers begin to use PUSH delivery for all kinds of media, security is a major concern. ZBand now features strong encryption, eliminating the need for costly conditional access (CA) systems. zBand also easily integrates with digital rights management (DRM) products. This combination offers the most secure delivery platform for Media on Demand systems available today. With Program Level Transport Encryption, zBand protects data with Certicom Security Builder™. By preventing signal theft of the IPTV service, zBand ensures the integrity of media delivery. zBand can PUSH targeted IPTV content to any network-connected device with hard disk storage, including PVRs, mobile phones, PCs, PDAs, PVPs and TVs.

- **Enterprise TV - Manageability, Targeting and Scheduling**

Enterprise businesses need an easy to manage IPTV solution that can reach dispersed corporate facilities, retail outlets and points-of-sale. zBand's stream targeting capabilities allow delivery of specific content, including encrypted live TV to exact locations. zBand automates time-consuming tasks such as user registration, play-list management and content deletion. zBand now also includes an enhanced toolkit that enables corporations to easily create their own Electronic Program Guides (EPG) to provide cable TV-like services. A bank, for example, could deliver a live network TV program on investment advice for the customer lobby while simultaneously delivering a VOD training program on selling loans for employees in a specific branch office. zBand's enhanced stream scheduling allows the delivery of multiple files for simultaneous viewing, and the ability to prioritise the scheduling of one program over another, which prevents scheduling conflicts.

- **Enterprise and Government Data Dissemination - Reliable and Cost-Effective Delivery** zBand's cost-effective and reliable delivery of any digital content over any network is ideal for enterprise and government data dissemination on the battlefield at home or abroad. Government service providers require real-time information delivery for command and control communications, surveillance, homeland security, disaster prevention and emergency response. zBand offers Quality of Service (QoS) and enhanced Forward Error Correction (FEC) to deliver mission-critical content with minimum latency or loss of data. Service providers responsible for failsafe operation of an enterprise application can rely on zBand by supporting fully redundant configurations with real-time failover. Service providers can also choose delivery rate and time to maximise bandwidth.



- **The zBand Architecture**

Located at the video headend, the zBand server aggregates and manages digital content from content sources and delivers the content to the zBand client. Embedded in terminal devices such as set-top boxes, PDAs, mobile phones, PCs, and portable communications platforms, the zBand client receives and presents the digital content to end users.

3.1.2.2 zBand Highlights

Security

- Program Level Transport Encryption with Certicom Security Builder secures the network with Elliptic Curve and AES encryption technologies
- Integrated Back Channel Registration provides a secure mechanism for exchanging encryption keys with server

Flexibility

- MSSQL database integration in addition to MySQL integration
- Enhanced ability to build a large EPG with improved client API with more query capability to the EPG
- Enables users to input their own content for storage in zBand cache and playout by zBand
- Multi-Port Streaming: multiple ports on one channel to support MPEG-4 style streams, reduces time to start service
- Open APIs for rapid customisation, integration and deployment
- Integration with Windows Media Server for full-stream service automation
- Stream encapsulation for all IP stream formats

Scalability

- Integrates with SkyStream Networks' Mediaplex-20™ Video Headend, iPlex™ Video Headend and Source Media Router (SMR) for a complete video delivery platform
- Increased targeting and client control, now up to tens-of thousands of sites

Manageability

- Integrated Back Channel Registration: automated information collection from targets, provides secure mechanism for exchanging encryption keys with server
- Automated Login Policy: integrates with any LDAP system, avoiding manual creation and monitoring of usernames and passwords
- Integrated Playlist Management: provides centrally-controlled playout control capabilities to enterprise client and automates playout of live and stored video
- Automated Deletion of content from server
- Enhanced Stream Scheduling enables seamless video scheduling for Corporate IPTV networks, stream prioritisation, drag-and-drop scheduling, and integration with live TV
- Complete automation of Envivio 4Caster™ Encoders for live video service deployment
- Secure content uploading and access to all zBand server functions from any Internet browser
- An embedded client-server kernel for set-top boxes and mobile devices
- Easy-to-use automated GUIs with drag-and-drop capability

Reliability

- Enhanced Stream Pacing on live streams featuring advanced FEC and rate control for higher quality content
- Full redundancy for mission-critical service deployment

3.1.2.3 Specifications

Operating Systems (server)

- Windows 2000
- Windows 2003

Operating Systems (client)

- Windows (XP, CE, 2000, 2003)
- Linux (PPC, x86)
- Solaris
- VxWorks

Maximum throughput

- 480 Mbps

Delivery protocols

- Pragmatic General Multicast (PGM)
- Asynchronous acknowledgement (ANAK)
- Delivery Storage Media Command and Control (DSM-CC)
- UDP multicast
- MPEG-2 transport streams
- User-defined carousels

Real-time Error Correction

- Forward Error Correction (FEC) with interleave support

Caching Protocols

- Apache
- Internet Explorer
- ICP
- HTTP Push

International Language Support

- Unicode (UTF-8)

Security Builder by Certicom™

- AES 128/192/256 bit
- ECC 128 bit [3,456bit RSA]
- ECC 192 bit [7,680bit RSA]
- ECC 256 bit [15,360bit RSA]

3.1.2.4 Applications

Broadcasters

- IPTV: Live TV and Push-based Media on Demand
- Video, movies, music and data

Enterprise Service Providers

- Business TV
- Employee Education and Training
- Communications and Human Resources
- Customer Education and Entertainment Programming
- Point-of-Sales Displays
- In-Store Music

Government Agencies

- Command, Control and Communications (C3)
- Emergency Response Support
- Real-Time Information Services
- Employee Communications and Human Resources

3.1.3 Bandwiz Download MagicCast™

Bandwiz's MagicCast™ is an innovative software package that makes download content distribution reliable and economic.

It ensures the delivery of large files (success even after a first transmission pass); it removes the need to re-transmit files (in order to recover lost packets), saves satellite bandwidth and back channel demands and improves the customer satisfaction.

The software package is basically an encoder that processes the file prior to transmission at the server side. There is a "on the fly" decoder (decoding by means a low priority thread) at the receiver side. Encoded file contains all redundant data needed to overcome interference.

Thanks to the encoding session, it is possible to recovery from delay, packet loss and interruption, since any other packet can replace any lost packet. The only requirement is that a sufficient number of encoded packets need to be received to ensure a prefect reconstruction of the original data. Overhead has to be adjusted to network environment and losses typical of the support (satellite, cable, etc.).

3.1.3.1 Features

- Applicable to any format of data.
- Simple API (COM, C, JNI) to allow integration to virtually any content delivery solution

- Unique coding schemes, which result in the highest efficiency of content delivery and download.
- Overcomes network losses with reliable coding algorithms
- Enables encoding either on the fly or pre-transmission.
- Efficient decoding on low-performance machines
- Enables resume over partially downloaded files

3.1.3.2 Benefits

- Utilizes bandwidth optimally on any kind of network - especially satellite with no back channel needed
- Ensures reliability for clients on very noisy, loosely or congested networks
- Substantial bandwidth savings compared to existing reliable IP protocols, no retransmissions required
- One-Shot download enabled.
- Allows Synchronized or closely-synchronized download.

3.1.3.3 Specifications

Interfaces available:

- C
- COM
- Java Native Interface (JNI)
- Independent of any transport layer.

Supported Platforms:

- Operating systems: Windows 98 or later; Linux 2.4 or later;
- Compiler: For Microsoft Windows - Visual C++ 6.0 Service Pack 4; For Linux –GNU G++ version 2.95 or later

Performance:

- Encoding Rate: Typically in excess of 100Mbps on a conventional single CPU server
- Served content limit: 1TeraB
- Decoder Rate: In excess of 10 Mbps on a 100Mhz/32RAM PC or alike

Hardware Requirements for Receiver Module:

- Processor – any typical commodity Intel CPU, at least Pentium I class recommended
- Memory – 32MRAM
- Disk Space – same as the size of the transmitted content + anticipated maximum loss percent of the content

Hardware Requirements for Transmitter Module:

- Processor – any typical commodity Intel CPU, at least Pentium III class
- Memory – 512MRAM
- Disk Space – same as the size of the transmitted content + anticipated maximum loss percent of the content
- Memory may replaced by disk space, but will cause pre-transmit delay

3.1.4 OpenCast Multicast File Transfer System

The OpenCast Multicast File Transfer system is the scaleable solution to perform efficient multi-point file content distribution over a multicast IP-based network. Combined with the Thales' award winning OPAL IP Encapsulator, OpenCast manages broadcast network content distribution and reception. OpenCast offers multicast scheduling and QoS management.

3.1.4.1 Overview

OpenCast is a scaleable and flexible solution, which can be integrated into existing content delivery network architecture or Thales' complete packages.

The OpenCast Multicast File Transfer System relies on two components:

- OpenCast Server: This server retrieves files to be sent, prepares them for their transfer through compression and encryption and insures a reliable and dependable transmission, based on the Reliable Multicast Transfer (RMT) protocols.
- OpenCast Receiver: A software solution bound to OpenCast server. OpenCast Receiver receives files sent by the OpenCast Server, and stores them onto the disk. OpenCast Receiver can also decrypt, uncompress and rebuild files according to the service parameters.

OpenCast is excellent for hybrid and asymmetric environments, combining wireless networks for the uplink and wired networks for the downlink.

3.1.4.2 Key Benefits

- Advanced files delivery (carousel, hot folder, mirroring)
- Multicast of up to 100 files simultaneously
- Up to 40 Mbps of data throughput support
- Standards-based Reliable Multicast Transfer protocols (NORM and ALC)
- Receiver ACK/NACK management (if return path available)
- Advanced FEC, file encryption and compression
- Scheduling and bandwidth management capabilities
- Powerful data flow control through the Thales' Opal IP Encapsulator
- Robust receivers and groups management (supervision and control)
- Remote or local supervision and configuration
- Exceptional, user-friendly Graphical User Interface

3.1.4.3 Processing Capabilities

OpenCast manages content compression using the Lempel-Ziv Welch algorithm and encryption, based on the Blowfish algorithm that runs with a 64 bit public key.

3.1.4.4 Flow Control

OpenCast allows any IP gateway to control the file transmission rate via a dedicated TCP tunnel. Coupled with the OPAL IP Encapsulator, this solution performs a unique and advanced "opportunistic data insertion" function by using Thales' Optimux® patented technology.

3.1.4.5 Receiver Management

The OpenCast Servers' Receiver Manager supervises and controls either a sole receiver, or a group of receivers.

Receiver management allows an operator to outline the actions (mainly file emissions) performed on receivers, supervise the receivers' state and send specific control commands to receivers.

The database and a powerful query editor offer in-depth content delivery follow-up.

3.1.4.6 Supervision & Configuration

The OpenCast Server Manager application provides an exceptionally intuitive Graphical User Interface to manage and supervise file delivery.

The OpenCast Receiver Manager is a GUI for monitoring the reception of files, received files, logs, graphs, and configuring the receiver. Both GUI applications can be connected to the server or the receiver either locally or remotely through TCP/IP.

A SDK can be provided to control both the OpenCast Server and the OpenCast Receiver. This SDK is based on a Windows dynamic link library (dll) and C++ header files.

3.1.4.7 Service Management & Transfers Reliability

Service Management

OpenCast features four types of service technology for file delivery:

- Standard service (clear identification of the files or folders to be sent)
- Carousel service
- Hot folder service
- Mirroring service.

Transfers Reliability

OpenCast is based on two standardized Reliable Multicast Transfer (RMT) protocols:

- NORM (Negative-acknowledgement (NACK)- Oriented Reliable Multicast)
- ALC (Asynchronous Layered Coding).

Both protocols insure reliable and robust file transmission, and perform error correction techniques based on the FEC algorithm to face to packet losses.

The NORM protocol is designed to provide a reliable delivery of data based on negative and positive acknowledgement, through NACK and ACK mechanisms. This protocol guarantees transfer reliability, and offers coordination between the receivers and the sender.

The ALC protocol combines data delivery in several layers to provide congestion controlled, reliable asynchronous content delivery.

3.1.4.8 Scheduling & Bandwidth Management

Available as an option, OpenCast includes scheduling and bandwidth management capabilities for planning the delivery of files, while optimising the available bandwidth.

3.1.4.9 Content Delivery Network

The OpenCast system can be integrated within Thales' OpenStream CDN end-to-end content delivery network solution to distribute rich media content for various applications such as Enterprise File Delivery, e-learning, or advertising.

3.1.4.10 Digital Video Content Delivery

The OpenCast system integrates with Thales' Store and Forward Solutions to offer efficient video program delivery to multiple stations, new services (i.e.: EPG, promotional channel) for broadcasters, and Enterprise Content Delivery applications for satellite operators.

3.1.4.11 Physical Characteristic

OpenCast Server:

- 1 Gbps Ethernet input for retrieving data stored on file server
- 2 10/100 Mbps Ethernet adapters for supervision and receivers messages

OpenCast Receiver:

- 1 10/100 Mbps Ethernet adapter for receiving data
- 1 10/100 Mbps Ethernet adapter for sending acknowledgement to the server

Supported platforms:

- OpenCast Receiver: Windows 98/2000/XP or Linux
- OpenCast Server: Win 2000/XP

3.1.5 The Multicast Dissemination Protocol (MDP) Toolkit

The Multicast Dissemination Protocol (MDP) provides reliable multicast file and data delivery on top of the generic UDP/IP multicast transport. Early work on MDP was deployed across the global Internet Multicast Backbone (Mbone) as part of the publicly available Image Multicaster (IMM) application.

The primary design goal of MDP is to develop a reliable, scalable, and efficient multicast transport protocol for use under a variety of heterogeneous network architectures. A secondary design goal is the seamless integration of novel erasure-based parity repairing techniques with selective multicast packet retransmission. Targeted operational factors that were key considerations throughout the protocol design process included:

- Use in heterogeneous, WAN infrastructures
- Use in mobile and wireless network conditions
- Operation in asymmetric delivery scenarios
- Support for small to large group sizes
- Support for group dynamics

MDP mainly uses selective negative acknowledgement (NACK) of missing data by receivers (clients) to enforce reliability.

In conjunction with selective NACK, the current MDP protocol uses a parity-based repairing mechanism based upon packet-level forward error correction coding concepts. The use of parity-based erasure repairing for multicast selective retransmission offers significant performance advantages (such as in error-prone wireless environments or across scaled WAN sessions). In MDP, encoded parity repair packets are normally sent only in response to repair requests by receivers so the algorithm adds no additional protocol overhead above pure selective retransmission methods. However, the protocol may be optionally configured to transmit “proactive” repair packets as part of the original data transmission block.

The MDP design supports distributed multicast session participation with little coordination among senders and receivers. The protocol allows senders and receivers to dynamically join and leave multicast sessions with a minimal amount of required overhead for control information and timing synchronisation among participants. As a result of this requirement, MDP protocol message headers contain some common information allowing receivers to easily synchronise to sources on a dynamic, *ad hoc* basis. In its common mode of operation, the MDP protocol uses multicast delivery mechanisms for both source and receiver transmissions, but the protocol permits optional unicast-based client feedback to MDP data sources. Optional unicast feedback may be suitable for use in asymmetric networks or in networks where only unidirectional multicast routing/delivery service exists.

3.1.6 Secure Data Broadcast (SDB)

Secure Data Broadcast is the most cost-effective way to distribute large amounts of data securely, using a guaranteed high-quality service that won’t choke your network.

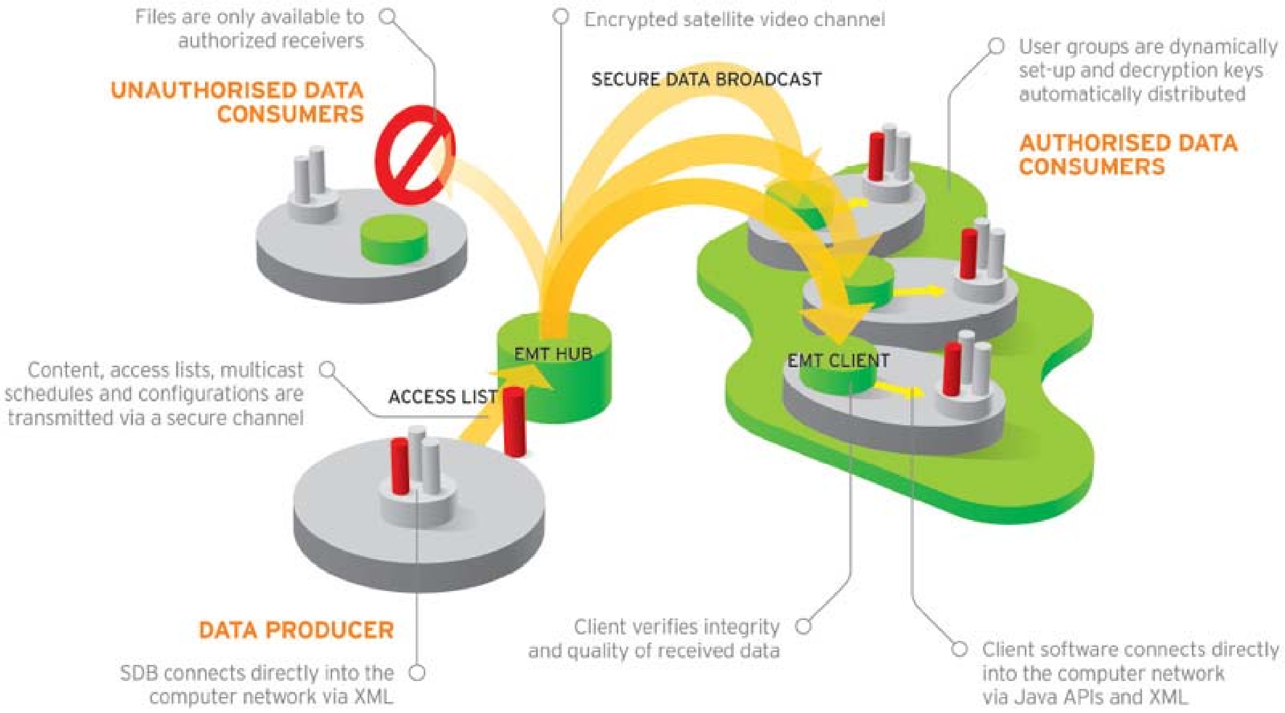
Built on Eutelsat‘s Multicast technology, **SDB** uses standard DVB-IP satellite technology to distribute voluminous data instantly throughout Europe, the Middle East, Asia and the Americas, at a fixed cost whatever the number of receiving sites.

Advanced security features such as:

- dynamic user group management
- conditional data access
- digital rights management
- data transfer encryption

ensure confidentiality and guarantee that data is not inadvertently intercepted.

To ensure service quality, **SDB** provides differential file repair, **customisable FEC** and **guaranteed fast delivery**.


Files are only available to authorized receivers
UNAUTHORISED DATA CONSUMERS
Encrypted satellite video channel
SECURE DATA BROADCAST
User groups are dynamically set-up and decryption keys automatically distributed
AUTHORISED DATA CONSUMERS
EMT HUB
EMT CLIENT
Content, access lists, multicast schedules and configurations are transmitted via a secure channel
ACCESS LIST
DATA PRODUCER
SDB connects directly into the computer network via XML
Client verifies integrity and quality of received data
Client software connects directly into the computer network via Java APIs and XML

3.1.6.1 Key Features

- Ready-to-use packaged service
- End-to-end solution including administrative features for: security, access control, quality of service, user group management, rights management
- Service provisioning on a "Pay-per-use" model
- No major hardware investment required

3.1.6.2 Key Benefits

- No specific satellite knowledge required
- Cost-effective pricing model (Pay-per-use)
- Guaranteed video quality
- Standard integration process
- Extended coverage from Eutelsat's satellite fleet

3.1.6.3 Technical Features

API (Application Programming Interface)
Manage multicast transmissions with simple scripts thanks to public functions of the API available for professional users.

Bandwidth On Demand
Book bandwidth slots as small as 64 Kbps for a few minutes up to 2 Mbps for years!

Basic and Low Cost Client Equipment
Setup your reception points with low cost equipment

Carousel

Repeat content transmissions as many times as you like.

CAS (Conditional Access System)
Encrypt all outgoing packets with a multi layered security structure.

DRM (Digital Rights Management)
Send your community video content scrambled with Windows Media© Digital Rights Management. End users will have to acquire the license to play the multimedia file.

FEC (Forward Error Correction)
Add redundant packets in your standard transmissions to recover packet loss.

Floating Licence (unlimited number of client installation)
Install the client software onto unlimited authorised reception points at fixed costs.

Multi Standard
All video streaming formats are supported (Windows Media©, RealNetworks™, QuickTime™...)

NVOD (Near Video On Demand)
NVOD enables PVR (Personal Video Recorder) functionality, already present in different STB.

Open Source Technology
Linux Based Servers
Java Programming Language
DVB / MPE (MultiProtocol Encapsulation) Transmission Protocol

Pure Multicast Protocol Efficiency
The use of satellite creates a wide private network where to take advantage of multicast power.

User Group Management System
Send content to restricted groups of your community.

Web Interface
Connect to the **Multicast Operation Center** using a simple Internet browser and set your preferences and multicast transmissions.

3.1.7 Comparison Table

The following table compares the main relevant features of the Satellite Data Broadcast Systems reviewed in the previous sections.

SDB Product	**Produced by**	**Supported Protocol**	**Open Source Technology**	**License Cost**	**DRM**	**CAS**	**Application Programming Interface**	**Database Engine**	**Max Supported Bitrate**	**Forward Error Correction**
Fazzt	KenCast	IP Multicast, UDP/IP, TCP/IP; RS-422/HDLC	No	Commercial	Not specified	External Solution to be integrated	Scripting Engine	External DD integrated through ODBC	90 Mbps	Fazzt FEC®
Zband	SkyStream	PGM ANAK DSM-CC UDP	No	Commercial	Not specified	Program Level Transport Encryption (Certicom Security)	Open APIs	MSSQL MySQL	480 Mbps	Advanced Algorithm based on R-S, with interleave support.
MagicCast	Bandwiz	Proprietary	No	Commercial	Not specified	External Solution to be integrated	COM, C, JNI	Not reported	Not reported	Internal Developed (similar Digital Fountain)
OpenCast	Thales	NORM ALC (FLUTE) UDP	No	Commercial	Not specified	Advanced algorithm (not specified)	SDK based on Windows dynamic library or C++ header files	Not reported	40 Mbps up to 100 files simultaneously	Advanced Algorithm based on Reed Solomon.
SDB	Eutelsat	Proprietary (FLUTE)	Yes	Free for the AXMEDIS scope	Windows Media DRM	CAOS	XML based	Postgresql API server (XML)	20 Mbps	Algorithm based on XOR.

3.2 Research Plan on Satellite Data Broadcast System

The Multicast File Delivery system is operational, inside the EMP, since mid of 2001. A big amount of log and Database entries was produced during the running of service. These data are constantly analysed by the Operational Team of OPENSKY. By this analysis was possible to extract a list of priorities in order to afford all points listed above, in an efficient manner.

The following list is the result of detailed analysis, in order to identify weaknesses of the system.

- Losses of Packets or Erasures
    - Local lost packets: receiving clients lose different sets of packets
        - The receiving workstation is managing a lot of tasks on the same time and it has not enough internal resource to treat the incoming data rate;
        - Losses are concentrated at the beginning of the transmission, means that workstation had a late notification of the start time of a given job
    - Global lost packets: all receiving client have lost the same group of packets (as direct consequence all users ask to repair the same group of packets in pull mode, with a possible phenomenon of NACK implosion)
        - The given set of packets has not been sent because it was dropped by the Encapsulator;
        - Lost packets represents the beginning of the content, the start time notification is sent too late inside the BSG;
- Building/Parsing cycle (data selection, formatting, sending, reception, and parsing at client side) (of the BSG is too much slow. All internal data treated by receiving clients after reception are already obsolete and compromising for a correct reception of the content;
- Encapsulator drops all packets exceeding the bit rate assigned to the related channel.

EUTELSAT has defined different research guidelines with the main scope of develop and integrate, in the existing solution, all features as soon as the research carries acceptable and useful results. At this purpose, the EUTELSAT activities spread out in this order:

- Drastic reduction of lost packets or erasures
    - Avoid to have a transmission with multiple and irregular burst: this could obstacle clients applications from correctly receiving the entirely of the content, due to the highly inconstant incoming data-rate;
    - Implementation of an efficient on-time signalisation of the start time of incoming transmission, in order to permit that listener application joins the starting transmission from the beginning;
    - Definition of an alternative strategy of error correction called erasure codes based on the principle of encoding all packets of a given file, in order to produce an enough number of encoded packet needed for any client to rebuild the original information;
- Bandwidth allocation
    - Computation in the most precise mode the estimated end of a given transmission: to know exactly (with a precision defined at second level) the end of a job, that allows a more efficient and optimised allocation of the next incoming transmissions;
    - Production of very regular data-rate curves: in order to avoid the packet transmission in burst very dangerous because it could determine both encapsulator dropping packets and lost packets at client side;
    - Higher bit-rate transmission: in the current version the maximum supported bit-rate is 2 Mbps; the target is to support at least 10 Mbps transmission. In this way it is simpler to dynamically allocate bandwidth to transmission with huge amount of data. In order to reach this result an adequate buffer strategy is essential at both server and client side;

- ACK/NACK advanced algorithm in order to avoid the NACK implosion coming when all users have lost the same group of packets. Define a strategy to send in multicast common lost packets by means of a repairing channel;
- Flexible definition of Metadata to be associated with original content
    - Action descriptor, containing a set of actions that have to be taken upon reception;
    - A more standard and rich description of the published content;

All activities present in the previous task list have different internal priorities. All tasks will be treated following this internal order.

3.3 Protocols for Data Distribution via Satellite

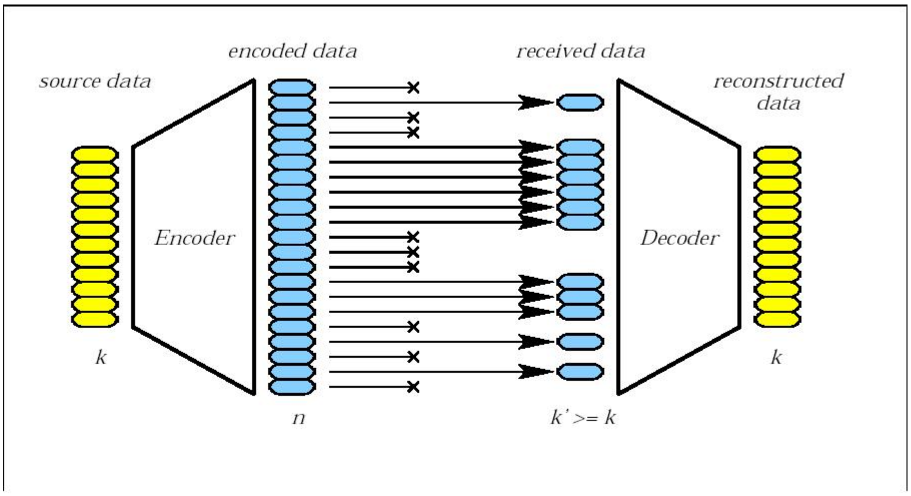
3.3.1 Redundancy Algorithms for Error Correction and Reconstruction of Lost Packets

One of the basic requirements of data distribution is integrity: content that reaches the final user must be complete and coherent. Across transmission, some packets may result corrupted or, even worst, missing.
Error detection is generally provided by the lower protocol layers, which use checksum to discard corrupted packets. The upper protocol layers thus have only to deal with erasures, i.e. missing data.
Erasures originates from uncorrectable errors at the link layers (indeed a rainstorm in the case of satellite communication), or from congestion in the network which causes otherwise valid packets to be dropped due to lack of buffers. Erasures are easier to deal with than errors, since the exact position of missing data is known.

Different approaches are used to repair to erasures. One of them, mostly used in unicast protocols, is the ARQ (Automatic Repeat request): missing packets are retransmitted on specific requests from the receiver. ARQ is not impressive in multicast transmissions, since the number of uncorrelated losses at different (groups of) receivers grows.
Another approach is the one used by FEC (Forward Error Correction) methods: the sender prevent losses by transmitting some amounts of redundant information, which allow the reconstruction of missing data at the receiver, without the need for retransmissions. FEC provides a faster recovery of missing packets, it renders the feedback channel unnecessary, and, moreover, it let different loss patterns to be recovered using the same set of transmitted data.

FEC algorithms are software implemented, and this has been represented an obstacle to their application in many multicast transmission protocols. FEC is considered computationally expensive since the encoding/decoding requires some processing on the data stream. Many studies have proved that FEC is less expensive than what is commonly thought, and it can be implemented in software without an excessive overhead.

Most of the FEC techniques are based on erasure codes, An (n, k) erasure code encodes k source data items into $n>k$ encoded data items. The encoding is such as *any* subset of k encoded items suffice to reconstruct the source data. All the n data are transmitted, so that the receiver can recover from up to n-k losses in a group of k. The fraction of the data which represents the source information is called the rate of the code, and it equals to k/n. The picture resumes the encoding/decoding process and compares the source and the encoded data.



A trivial code is a (*k+1,k*) code. In this case, a single redundant item is built using *k* source data items, and the rate of the code is *k/(k+1)*, insuring a good use of the bandwidth. An example of *(k+1,k)* code is the XOR, where each redundant item is obtained by simple XOR on the *k* source items. Each code, perhaps, has a limit of how many errors it can detect and correct. Hamming codes are a widely used form of FEC when single errors need to be corrected. Reed Solomon coding is a more complex technique that can detect and correct multiple errors.

Hamming codes are a simple form of forward error correction that can be implemented very inexpensively. But the fact this code can correct only single errors become especially important when considering burst errors. However, using interleaving, multiple Hamming codes can be combined in a way that better handles them. Interleaving is a popular approach to make a bursty channel look more like an independent-error channel for which there are many error correcting codes to work with. In an interleaving system, the data is streamed into an error control encoder which applies to error coding. The interleaver then alternates between code words sending out a bit at a time. The receiver would receive these bits and de-interleave them back into the original coded message. The advantage of this system is it allows a burst error to be distributed over the data sequence, creating a series of single bit errors that can be handled using a wide variety of effective coding techniques. As long as the number of corrupt data bits in a burst is less than the number of code words that the data is spread amongst, then a simple single-bit correcting error code can be used. Otherwise, the code must be able to deal with multiple bit errors.

Most appreciated erasure codes are based on the Reed-Solomon codes. These codes operate on *s*-bit symbols instead of just single bits. Any errors within a symbol count as one error. This means that even if all *s* bits are bad, it is still counted as just one error, thus increasing its effectiveness in correcting burst errors, Another advantage of Reed Solomon coding is that the *r* correctable errors within a code word can exist anywhere in the code word. Although the errors can be sequential, they do not have to be. This provides very robust error detection and correction, but it comes at the price of increased processing power. Because of this, many Reed Solomon encoders/decoders are implemented in hardware instead of software. Since Reed Solomon coding can detect multiple consecutive bit errors within one code word, it is well suited for satellite data distribution, where errors typically happen in burst.

Another peculiarity of FEC implementations is the moment they apply: ‘offline’ or ‘online’. Some FEC may work ‘offline’, meaning that the content is pre-processed in order to add redundancy data, and then it is transmitted. On the receiver side, the decoding is also done after reception. This form is expressly favourable for non real-time applications, using a communication speed much higher than the encoding/decoding speed.

The Eutelsat Satellite Data Broadcast system already integrates a simple online FEC protocol using the XOR parity-based erasure reparation. This method provides a good flexibility in the choice of redundancy added to source data. Adding also a flexibility in the interleaving, according to the size of the content, could increase the ability to repair burst errors without expanding the overhead.

3.3.2 Reliable Multicast over Satellite

This activity is dedicated to the exploration of different strategy in order to implement an advanced NACK-based algorithm, taking into account characteristics of Multicast File Delivery using satellite channels.

3.3.2.1 Description

Reliable Multicast over Satellite is a complex problem due to the capacity of the forward channel versus the available return channel.

The sender has a limited capacity for responding to reports of data loss. Simultaneous retransmission requests from large numbers of receivers can lead to sender overload, causing the well-known NACK implosion problem.

Additionally, receivers in a multicast group may experience widely different packet loss rates depending on their local weather conditions and signal strength.

In case of multiple requests for the same lost packet, the sender can retransmit to the entire group using an appropriate repairing channel. In order to scale loss recovery to large multicast groups, efficient mechanisms are needed to control NACK implosions and to distribute the load for retransmissions [ARM].

3.3.2.2 Requirements for an Ideal Protocol

We recall an example application in which millions of clients want to download a new release of software over the course of several days. In this application, we assume that there is a distribution server and that the server will send out a stream of packets (using either broadcast or multicast) as long as there are clients attempting to download the new release. This software download application highlights several important features common to many similar applications that must distribute bulk data. In addition to keeping network traffic to a minimum, a scalable protocol for distributing the software using multicast should be:

Reliable: The file is guaranteed to be delivered in its entirety to all receivers.

Efficient: Both the total number of packets each client needs to receive and the amount of time required to process the received packets to reconstruct the file should be minimal. Ideally, the total time for the download for each client should be no more than it would be had point-to-point connections been used.

On demand: Clients may initiate the download at their discretion, implying that different clients may start the download at widely disparate times. Clients may sporadically be interrupted and continue the download at a later time.

Tolerant: The protocol should tolerate a heterogeneous population of receivers, especially a variety of end-to-end packet loss rates and data rates.

We also state our assumptions regarding channel characteristics. IP multicast on the Internet, satellite transmission, wireless transmission, and cable transmission are representative of channels we consider. Perhaps the most important property of these channels is that the return feedback channel from the clients to the server is typically of limited capacity, or is non-existent. This is especially applicable to satellite transmission.

These channels are generally packet based, and each packet has a header including a unique identifier. They are best-effort channels designed to attempt to deliver all packets, but frequently packets are lost or corrupted. Wireless networks are particularly prone to high rates of packet loss and all of the networks we describe are prone to bursty loss periods. We assume that error-correcting codes are used to correct and detect errors within a packet. But if a packet contains more errors than can be corrected, it is discarded and treated as a loss.

The requirement that the solution be reliable, efficient, and on demand implies that client robustness to missing packets is crucial. For example, a client may sporadically be interrupted, continuing the download several times before completion. During the interruptions the server will still be sending out a stream of packets that an interrupted client will miss. The efficiency requirement implies that the total length of all the packets such a client has to receive in order to recover the file should be roughly equal to the total length of the file.

3.3.2.3 NACK-based solution

A one-to-many scenario as ours sees a sender transmitting data packets to multiple receivers who joined the multicast group; in principle the sender need not to know the receivers identities, and thus is not aware of the regular reception of data.

Reliability and efficiency are two of the key concepts of multicast transport. To ensure reliability, several mechanisms of control are available. In early ACK-based protocols, the sender is responsible of both the loss detection and the recovery. Every time a receiver accepts and consumes a packet, it sends an ACKnowledgement message back to the sender. The sender is expected to keep on sending packets until it has received an ACK message. One of the difficulties that rise in this kind of notification is the "implosion" of signaling at a source from many receivers; it produces a waste of bandwidth and may result in a denial of resource to the group members. Moreover, this kind of protocols does not scale well to a large number of receivers, considering that multicast sessions are mainly used with large groups.

In a NACK-based scheme, the loss detection responsibility is up to each receiver: a receiver sends a NACK (Negative-ACKnowledgement) towards the sender as soon as it detects a loss packet. The numbers of NACK messages is certainly lower than the possible ACKs, but however the problem turns into a NACK implosion problem when a large number of receivers have subscribed to the multicast session.

The NACK-Oriented Reliable Multicast (NORM) [35] protocol is designed to provide end-to-end reliable transport of bulk data objects or streams over generic IP multicast routing and forwarding services. NORM uses a selective, negative acknowledgement (NACK) mechanism for transport reliability and offers additional protocol mechanisms to conduct reliable multicast sessions with limited "a priori" coordination among senders and receivers.

Since each data packet is labelled by a unique sequence number, receivers detect losses primarily on receipt of an out-of-order data packet or may also detect losses if no data have arrived after the maximum sending interval has past. When a loss is detected, the receiver sends a NACK to the source requesting the lost data packet.

In order to contain the congestion of the network, multiple NACKs from different receivers are cached and “fused”.

The sender responds to the first NACK by multicasting a repair to the group. It then ignores subsequent NACKs for this packet for a fixed amount of time (e.g., for the estimated RTT to the farthest receiver in the group).

Since NACKs and repair data may also be lost, a receiver should resend a NACK if it does not receive the repair within a certain time limit. To identify new NACKs, each NACK contains a NACK count to indicate how many times the receiver has requested a lost data packet.

The sender maintains the highest NACK count associated with each requested repair. If it receives a NACK with a higher NACK count, it assumes that the previous retransmission was lost and multicasts the repair to the group again.

Congestion control is a key task in reliable multicast along with error control. Without a proper congestion control mechanism, multicast protocols cause the unfair sharing of network bandwidth with other flows, especially TCP flows in the network and eventually congestion collapse. Several congestion control schemes such as TRAMCC and MTCP have been proposed for tree-based reliable multicast protocols.

In the NORM protocol a congestion control scheme is specified to allow the NORM protocol fairly share available network bandwidth with other transport protocols. It is capable of operating with both reciprocal multicast routing among senders and receivers and with asymmetric connectivity (possibly a unicast return path) from the senders to receivers. The protocol offers a number of features to allow different types of applications or possibly other higher level transport protocols to utilize its service in different ways. For these raisons, this standard should adapt well to the Satellite Distribution Channel.

Conventionally, the NORM sender transmits application-enqueued data content, providing repair transmissions (usually in the form of FEC messages) only when requested by NACKs from the receivers. However, the application may also configure NORM to proactively send some amount of FEC content along with the original data content to create a "robust" transmission that, in some cases, may be reliably received without any NACKing activity. This can allow for some degree of reliable protocol operation even without receiver feedback available. NORM senders may also requeue (within the limits of "transmit cache" settings) objects for repeat transmission, and receivers may combine together multiple transmissions to reliably receive content. Additionally, hybrid proactive/reactive FEC repair operation is possible with the receiver NACK process as a "backup" for when network packet loss exceeds the repair capability of the proactive FEC settings.

3.3.3 Signalling Channel

- Signaling Channel: managing a good coordination between servers and receiving clients (announcement channel, internal clock, customised messages, etc.)

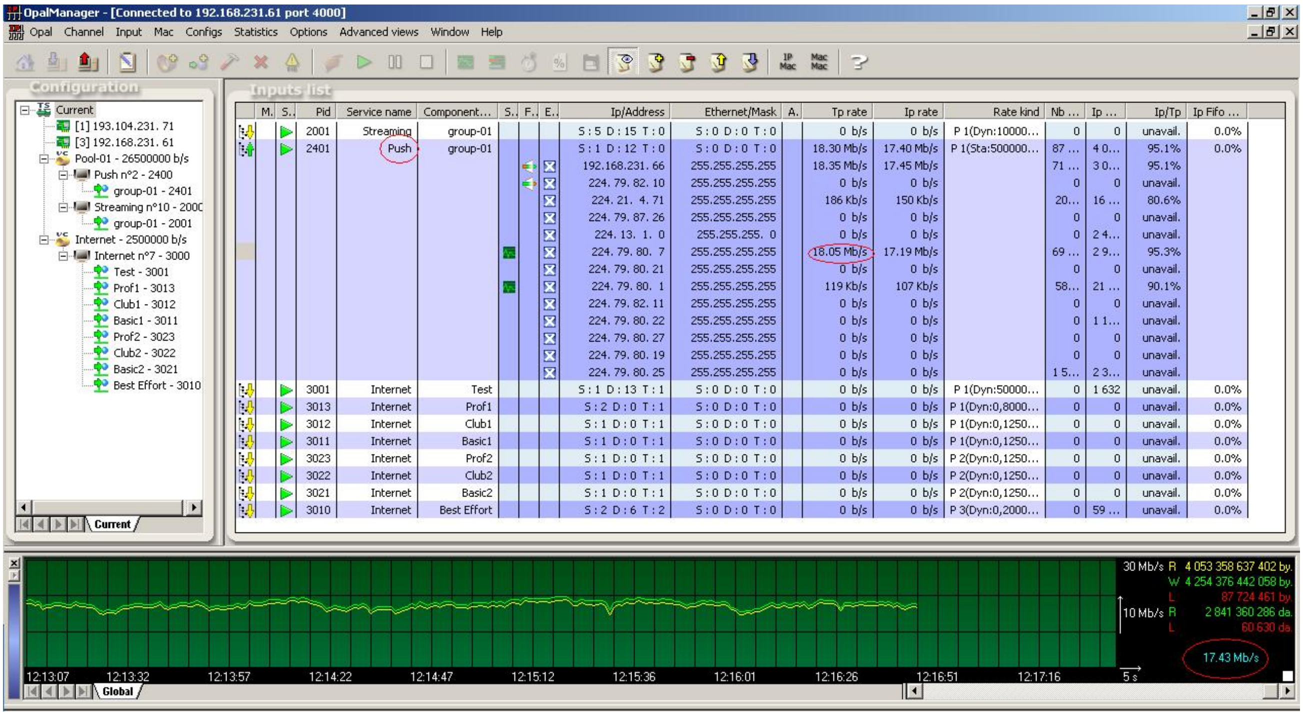
3.4 Bandwidth Allocation

3.4.1 Priority Manager

- Management of priorities and relative weights in jobs allocation: a system capable to manage both priorities and weight in separate contexts. Bandwidth is prior assigned to job with the max priority; among jobs with the same priority the bandwidth is assigned on a weight basis. Once satisfied all jobs belonging to given level of priority, then the residual bandwidth is re-distributed to jobs with lower priorities.
- "Best effort" traffic: it directly derives from the dynamic allocation of jobs. In the previous context, they can be compared to jobs with the lowest priority and weight.

3.4.2 Bandwidth Regulator

Each scheduled transmission has associated a bandwidth that corresponds to a portion of the available bandwidth on the transmission channel that is reserved/ dedicated to that service. Even in the case the system grants a dynamic managing of the bandwidth, with effective time spread variations of the bandwidth, the challenge of respecting these constraints is always valid. The goal is, of course, to not exceed the bandwidth assigned to the service, to avoid automatic dropping of exceeding data (according to the politics chosen). Another key point is to grant a constant flow of data in the stream. This is essential to ensure a regular reception to clients, without bursts. Having suddenly a large amount of data to be treated in a short time is often a tricky condition for a receiver; and this may originate errors or losses. Bandwidth regulator mechanisms are used to respect the stream bandwidth without burst during the transmission. The regulator integrated in the transmission system ensures regular transmissions, also at high bandwidth, as the graph shows. This has allowed, as expected, to improve the quality of receptions, with a disappearance of those errors, common to all the receiving stations, that were observed in coincidence with burst on the server side.



OpalManager - [Connected to 192.168.231.61 port 4000]

- Current
  - [1] 193.104.231. 71
  - [3] 192.168.231. 61
  - Pool-01 - 26500000 b/s
    - Push n°2 - 2400
      - group-01 - 2401
    - Streaming n°10 - 2000
      - group-01 - 2001
  - Internet - 2500000 b/s
    - Internet n°7 - 3000
      - Test - 3001
      - Prof1 - 3013
      - Club1 - 3012
      - Basic1 - 3011
      - Prof2 - 3023
      - Club2 - 3022
      - Basic2 - 3021
      - Best Effort - 3010

	M.	S..	Pid	Service name	Component...	S..	F..	E..	Ip/Address	Ethernet/Mask	A.	Tp rate	Ip rate	Rate kind	Nb ...	Ip ...	Ip/Tp	Ip Fifo ...
		▶	2001	Streaming	group-01				S : 5 D : 15 T : 0	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 1(Dyn:10000...	0	0	unavail.	0.0%
		▶	2401	Push	group-01				S : 1 D : 12 T : 0	S : 0 D : 0 T : 0		18.30 Mb/s	17.40 Mb/s	P 1(Sta:500000...	87 ...	4 0...	95.1%	0.0%
								☒	192.168.231. 66	255.255.255.255		18.35 Mb/s	17.45 Mb/s		71 ...	3 0...	95.1%	
								☒	224. 79. 82. 10	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 21. 4. 71	255.255.255.255		186 Kb/s	150 Kb/s		20...	16 ...	80.6%	
								☒	224. 79. 87. 26	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 13. 1. 0	255.255.255. 0		0 b/s	0 b/s		0	2 4...	unavail.	
								☒	224. 79. 80. 7	255.255.255.255		18.05 Mb/s	17.19 Mb/s		69 ...	2 9...	95.3%	
								☒	224. 79. 80. 21	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 79. 80. 1	255.255.255.255		119 Kb/s	107 Kb/s		58...	21 ...	90.1%	
								☒	224. 79. 82. 11	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 79. 80. 22	255.255.255.255		0 b/s	0 b/s		0	1 1...	unavail.	
								☒	224. 79. 80. 27	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 79. 80. 19	255.255.255.255		0 b/s	0 b/s		0	0	unavail.	
								☒	224. 79. 80. 25	255.255.255.255		0 b/s	0 b/s		1 5...	2 3...	unavail.	
		▶	3001	Internet	Test				S : 1 D : 13 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 1(Dyn:50000...	0	1 632	unavail.	0.0%
		▶	3013	Internet	Prof1				S : 2 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 1(Dyn:0,8000...	0	0	unavail.	0.0%
		▶	3012	Internet	Club1				S : 1 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 1(Dyn:0,1250...	0	0	unavail.	0.0%
		▶	3011	Internet	Basic1				S : 1 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 1(Dyn:0,1250...	0	0	unavail.	0.0%
		▶	3023	Internet	Prof2				S : 1 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 2(Dyn:0,1250...	0	0	unavail.	0.0%
		▶	3022	Internet	Club2				S : 1 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 2(Dyn:0,1250...	0	0	unavail.	0.0%
		▶	3021	Internet	Basic2				S : 1 D : 0 T : 1	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 2(Dyn:0,1250...	0	0	unavail.	0.0%
		▶	3010	Internet	Best Effort				S : 2 D : 6 T : 2	S : 0 D : 0 T : 0		0 b/s	0 b/s	P 3(Dyn:0,2000...	0	59 ...	unavail.	0.0%

3.4.3 Bandwidth Manager

- Bandwidth Manager
  - Semi-static solution with "director": the actor is a Director that manages all active threads of transmission. It can decide to speed up/down the local bandwidth parameter of each transmitting agent.
  - Fully dynamic solution with "traffic shaper": the actor is an entity able to centralise decisions about dynamic bandwidth variations. The traffic shaper, in this case, makes a decision and executes it. Some efforts should be produced in synchronizing the Unicast with the Multicast variations, in order to allow that a less use of bandwidth by the Internet user could be immediately assigned (even for few seconds) to the Multicast pool, and maybe satisfying some pending ‘best effort’ transmissions.

3.4.4 Automatic Allocator

- Automatic bandwidth allocation: the system should be able to support requests like volume-based reservations. In this scenario, the transfer of data is carried out without any prior reservation of bandwidth channel. The content has to be sent before a given date (deadline), with some bandwidth constraints (not less of 512 Kbps, not more than 1 Mbps, etc.), with some possible repetition (global or partial). The billing is based on the volume of data sent by satellite.

3.5 Metadata

3.5.1 Action Manager

One of the first requirements demanded by the AXMEDIS project was the caching of the content on the client: AXMEDIS Objects transmitted by satellite are to be gathered together in a proper CACHE area, where they are available for composition and formatting etc.

The existing transmission protocol for the EUTELSAT Data Broadcast wanted the downloaded content to be stored on a specified content area, but with a precise protocol.. The content is stocked according to a an arborescence that reflects the origins of the content (Distributor/Content). Also, each content folder is completed with metadata files used for example for further receptions and updates of the downloaded files.

In the case of AXMEDIS, it was clear that the files (AXMEDIS Objects) received via satellite had to be filtered from OPENSKY metadata and put together in a common CACHE AREA, where filtering and other post-reception handling were performed.
The "move" of the content files was not a trivial operation; but there were, of course, several ways to integrate it in the system.
The one that has been chosen and implemented is the one that considers this operation as an example of actions that can be required and performed on the content (at the client side) after the reception.
The distributor, or in general who's in charge of the transmissions, can decide to associate to a certain content some actions to be performed along with the distribution via satellite. For example several contents can be zipped together and sent as one single instance; but once on the client they have to be restored as unitary items. Or the distributor wants to be informed of the correct reception of the content from the enabled receiving stations.
Observing these actions from this point of view, the idea was to consider them as properties of the content, with, on the client, an Action Manager charged of firing them exactly when expected.
In this manner, the "move"action has been generalized as a property of the package; when preparing an OPENSKY package for AXMEDIS content, the option move is selected, and along with it the with parameters as the CACHE area to move the files in.
The Action Manager has been implemented and integrated in the prototype of the satellite distribution demonstrator, as in accompaining deliverable DE9.3.3 First prototype of content production and distribution in push and on-demand for I-TV.

3.5.2 Internal Communication

Interface to Publisher via XML-RPC: standardisation of all type of interaction both external (partner communicate with the system) and internal (communication among internal modules of the system).
The APIs use an XML protocol encapsulated in HTTPS protocol, and their data format is XML.
The set of external API of the EUTELSAT Push system includes functions for content packaging and program scheduling and activation. They are used in the integration of the AXMEDIS P&P tool with the Satellite Distribution Channel. With the integration, once a Distributor defines a Programme and chooses the satellite channel for the delivering, the calls to the API will prepare the corresponding packages and programs on the OPENSKY platform, and finally activate the distribution.

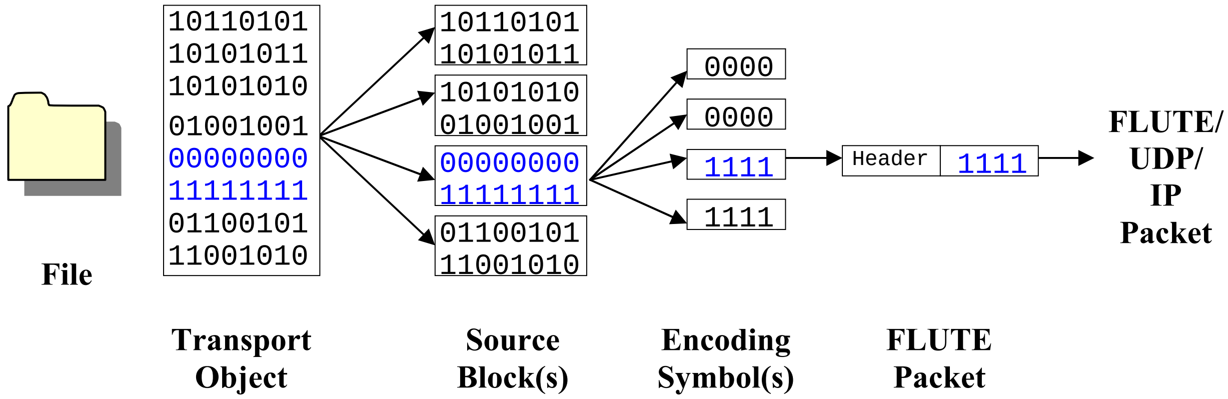
3.6 Protocol Standardization

This section concerns the study of existing standard multicast protocols, in order to consider the possibility of lining up the Eutelsat Multicast File Delivery Protocol with other standard technologies. The aim is to analyse the charactertistics and qualities of the top of the edge technologies in the sector, and make a system that is compliant to them, with all the advantages that this may imply.
Besides the Multicast Dissemination Protocol already presented in the previous sections, the upcoming FLUTE protocol has been studied and chosen as standard to be adopted by the EUTELSAT system.

3.6.1 FLUTE

FLUTE (File Delivery over Undirectional Transport) is a protocol for the unidirectional delivery of files over the Internet or unidirectional systems from one or more senders to one or more receivers, particularly suited to multicast networks.
In June 2004 the DVB-CBMS group launched a Call For Technologies (CFT) to fit IP DataCasting in DVB_H; the call covered several domains, from those typical of mobile environment, as the mobility and roaming , to more general others, as the coding formats, content delivery protocols, Electronic Service Guide (ESG) and network performance and QoS. The group finally selected the ALC/FLUTE protocol, proposed and supported by Nokia, TeliaSonera, Vodafone, Elisa, SWelcom and T-Systems.
FLUTE is built on top of the Asynchronous Layered Coding (ALC) Protocol Instantiation, the base protocol designed for massively scalable multicast distribution. ALC is part of the Layered Coding Transport (LCT) Building Block, that provides transport level support for reliable content delivery and stream delivery

protocols. ALC combines the LCT building block, a Congestion Control (CC) building block to provide congestion controlled reliable asynchronous delivery, and a Forward Error Correction (FEC) building block for improved reliability. FLUTE inherits all the requirements from ALC.
FLUTE inherits the session concept from the ALC and thus from the LCT. An ACL/LCT session is formed by a set of grouped ALC/LCT channels, and a single sender sending packets with ALC/LCT headers. An ALC/LCT channel is defined by the combination of a sender (source) and a multicast address (target). An ALC/LCT header contains the Transport Session Identifier (TSI). Transport Object Identifier (TOI) is useful when multiple objects are carried within a session: the TOI identifies which object the data in the packet was generated from. A session is uniquely identified by the couple source IP address and TSI.A receiver joins a channel to start to receive the data packets sent to the channel by the sender, and the receiver leaves the channel to stop receiving data packets from channel.
The figure below shows how a file is split into FLUTE packets:



FLUTE Packet composition

assume that the user wants to send a file, which is the Transport Object for the FLUTE protocol. Based on the transport object length, the Encoding Symbol Length and the Maximum Source Block Length a FLUTE sender calculates the source block structure, i.e. the number of source blocks and their lengths. Each source block is then fragmented into source symbols. If FEC is used, then parity symbols are calculated. Source symbols and parity symbols (if present) give the encoding symbols for the FLUTE protocol. Then a FLUTE packet is constructed from a FLUTE header and an encoding symbol. The FLUTE packet is then ready for UDP/IP delivery. The Encoding Symbol Length and the Maximum Source Block Length are configurable by the user of the FLUTE sender; they are then communicated to the FLUTE receiver in the FLUTE header, or using a special transport object, the File Delivery Table (FDT).
The advantages rising from the use of the FLUTE protocol for the transmission via satellite are many.
First of all, there is the completeness of the protocol. FLUTE already provides some of the blocks required for a reliable multicast, as the FEC for repairing losses, the grouping mechanism for target-oriented multicast, and carousel mechanism for repeated transmissions.
The combined use of FEC and data carousel with looped transmissions [37] can assure good protection against packet loss.
On the other hand in fact, as FLUTE uses unidirectional transport, it does not provide a method for senders to verify the successful reception of receivers, which is really useful in the B2B environment.
To conclude, a very positive point of the FLUTE protocol is that several open-source implementations are available.

4 The receiving devices: PC and STB

The third part of the T4.8.1 focuses on the distribution to two different devices: PC and STB. This section introduces this task and then report on the STB activities of research and then integration in the AXMEDIS platform.

4.1 Differences and similarities

The Satellite Data Broadcast System of EUTELSAT is not dependent on a specific receiving device: being the system based on software application, the same can be adapted to several platforms. The activity in the present workpackage, whose analysis results were presented in the previous sections, has been led in a first step without any specific reference to the targeted device, but focusing only on the distribution problematics in general. This is the case of the previous sections, analysing the distribution mechanism and the optimisations. This has been possible because, although existing evident differences between a classical PC and a STB in terms of use, the content reception on the two devices works exactly in the same way. Analysis of the PVR and STB's generality and strategic aspects were done in the previous tasks T4.8.2 and T4.8.3, and reported in sections 5.3 and 6.3. In this section we refer only to the specific aspects in the structure of the STB and its integration in the AXMEDIS platform.

4.2 Satellite Data Broadcast to the AXMEDIS STB

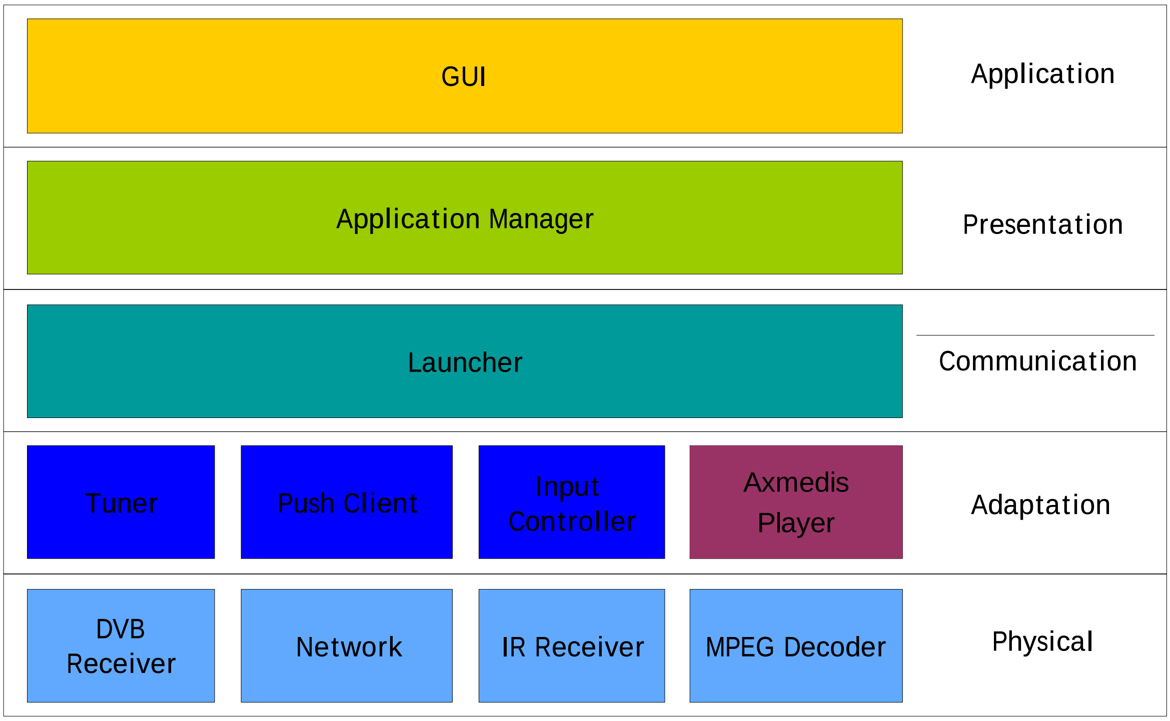
In T4.8.1 (Content Distribution towards both Set Top Box and PC-based clients) within the AXMEDIS development the effort has been to enforce the AXMEDIS model into STB. The STB has to able to receive multimedia contents in the AXMEDIS format but also MPEG4 and MPEG-21 format from a satellite network and to provide them to the final users through a normal TV set.

The STB must be able to get data from a DVB-S connection, using the server side infrastructure of the EUTELSAT OPENSKY™ Multimedia Platform

For the WP9.3.2.2 is the Demonstrator MBI has identified the main interactions with the existing AXMEDIS applications and has developed the adaptation of MBI STB middleware to satisfy the requirements of the AXMEDIS components (Axom library).

The MBI's AXMEDIS STB is a x86 based CPU Set-Top device with integrated chipset for hardware video decoding and DVB satellite front-end. The software is based on Linux Operating System (OS), Debian distribution, version 3.1. MBI have developed a middleware, codenamed DINTV, that sits on top of the Linux OS.

From the Adaptation to the Presentation layers DINTV consists of a set of modules to provide all the functions of the STB. Each module is highly independent from each other, while the interface paradigm is based on asynchronous messages travelling on TCP/IP channels. The general structure is highly hierarchical: each module is linked to one parent module and possibly one or more children: in such way each module knows how to communicate with its peers, but has no knowledge of their implementation. The use of standard protocols (TCP) for the interconnection of the modules, makes it possible to have them implemented in different languages (i.e. C, C++, Java, Python, etc).

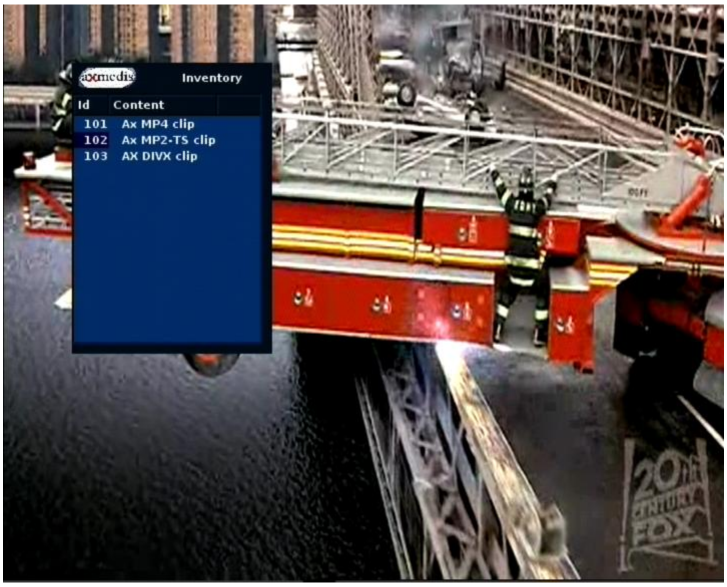


MBI STB software stack

At the data level the DVB Receiver allows the STB to tune to a satellite transponder and receive data from selected DVB Pids. The DVB software driver also presents a network interface (dvb-net) for the incoming IP data encapsulated in DVB streams via Multi Protocol Encapsulation (MPE). The Network interfaces of the STB transmit/receive IP data via Ethernet, Pstn modem and dvb-net (receive only). With the Infrared Receiver driver the STB receives keys from a Remote Control or IR keyboard, while the MPEG decoder module allows the hardware accelerated decoding of the video from both file or stream.

The STB, for this demonstrator, acts as a slave device of the Push service. The OPENSKY Listener (OSListener) runs as a background task on the STB and receives the Push packages that are targeted to the STB device it is running on. The reception of a package is enabled if the devices belongs to a Group to which the packaged is delivered. A device may belong to multiple Groups. The STB can react automatically upon reception of a package, decompress it if necessary, and present the new contents to the user. It is also possible to clear a content from the STB, by sending an empty package with the same name of the one that delivered the content. This results in a powerful means of handling the media list of the STBs, in defined Groups, entirely from the Distributor, or Service Provider side.

The STB does not show the GUI available for a PC, as described before, since that one would be completely inadequate for a STB user. The STB Push model as described above, implies that the STB retains its typical consumer-electronics user interface made up of menus, lists and banners, while the Push reception activity runs in background. The figure below shows an example of list that allows the user to navigate the contents via remote control.



Id	Content
101	Ax MP4 clip
102	Ax MP2-TS clip
103	AX DIVX clip

Example of content guide for STB

The widgets graphics system used is Trolltech's QT. The input (from Remote Control or Keyboard) to the QT application is forwarded by means of MBI TCP messages (as from sw stack). The Application Manager handles focus, hiding, input message forwarding.

The AXPlayer, as from the figure below, is the key module that has been developed, starting from a previous DINTV player, to provide the mentioned Axmedis functionalities. It is the MBI-STB middleware module integrating the AXOM library, it feeds the MPEG2/4 hardware decoder (Sigma Designs EM8471) of the STB with the data from the AXOM. While the Axom interface is standard C++ library istream interface the Sigma decoder is fed via memory buffer. The AxPlayer can play all the multimedia content types the Sigma hw can. Particular effort has been put by MBI to overcome the limitations on non-streamable types where in depth control has been implemented on the Sigma low level library side.

An important requirement of such a system is that the mime type and the resource file extension be correctly set in the axm metadata (e.g. mime "video/mpeg" for an MP4 resource would not play on the STB).

For non-Axmedis contents the STB needs an index XML file (or a tree of them) listing the contents that must be presented to the user in the STB GUI. They come from the concept of the consumer STB's "channel list". Since this contents index files did not fit well with the Axmedis model and the distribution of WP9.3, the solution has been found by adding the following functionalities to the STB "tuner" module: scan a base path for the axm objects, verify integrity of the objects received, parse metadata to detect resources and their mime type and finally map the resources as contents for the STB GUI.

4.3 Streaming to STB

Several choices of STB's were being considered during the research activities, to be summarised into three main categories:

- PC-based STB client
- PVR (HD) STB (i.e. STB with a hard-disk)
- Commercially optimal STB with a thin client

A number of choices were researched in each category, but eventually the researchers focused on the two choices between a PC-based STB and commercially widely accepted device. The PVR (HD) STB was eliminated. While simple in implementation, the HD STB is expensive for the consumer and would not have potential mass market application.

As commercial partners, TEO and Elion, among the key objectives of research, focused on demonstrating on how AXMEDIS can work in real world, where consideration of cost/benefit are main criteria for determining whether one technology is adopted over another. The key criteria for an STB being researched were as follows:

- Widely accepted, deployable in commercial environment, affordable to the consumer
- Integrate able with commercial closed-system IPTV solution
- Functionality development should be possible with ADK (application development kit), but without the proprietary SDK (software development kit)
- Technical documentation and support should be available from the manufacturer/distributor.

When considering the choice of end user STB device for interactive TV applications, the scope of interactivity is a function of processing memory and storage space available on the STB. The higher the processing memory and storage capacity of the STB, the more expensive and complex it becomes, making deployment of narrow interest services unfeasible. Therefore, the objective of research was to find solutions for an STB that is used in massive deployment of traditional IPTV services.

After detailed analysis of available STB technologies, undertaken by TEO, Elion, two STB options for the TEO demonstrator were identified:

- Motorola/Kreatel STB
- PC-based x86 experimental STB.

As part of the research activities, KTU has developed a prototype of IP STB boards. This STB is based on x86 1GHz CPU with 256MB of RAM at minimum. This STB was developed with Linux based OS and can be developed with Hard disk. There are also included Hardware MPEG2/4 playback and AES, 3DES hardware accelerators. This STB has no big hardware limitation as Kreatel.

Eventually after analysis of available STB options, the Kreatel 1720 STB was chosen. The facts that supported the decision were:

- The issues with AXOM module are more related to the usage of different compilers. Those issues may be solved by fixing incompatible parts of code. Some work has been already done by MBI, however, several open compilation problems left.
- After code optimization and striping of debug symbols, the AXOM size was reduced to less than 4MB which is reasonable for Kreatel STB.
- STB has built-in hardware DVB-CSA descrambler which makes usage of protected AXMEDIS object resource streams feasible.

Kreatel STB

This hybrid IPTV/DBV-T STB (see picture below) is successfully used as a commercial solution by TEO since the launch of its IPTV services.

Kreatel Set-top-box

Kreatel IP-STB 1720 technical characteristics:

- Hardware:
    - Microprocessor MIPS processor with integrated TV video processing and MPEG decoder, performance 420 DMIPS;
    - Main memory 128 MB DRAM;
    - Video memory MPEG-2 shared with main memory MPEG-4 16MB;
    - Accessories Infrared remote control Infrared keyboard (optional).
- Operating systems
    - Linux.
- Streaming audio:
    - MPEG (Layer 1,2,3);
    - PCM;
    - AC3.
- Streaming video:
    - MPEG-1 - 800 kbits/s to 3 Mbits/s, CIF 352x288;
    - MPEG-2 transport stream - PAT, PMT, video and audio streams, constant and variable bit rate, 2-25 Mbit/s, MP@ML;
    - H.264 - PAT, PMT, video and audio streams, up to 3 Mbit/s;
    - VC-1 - PAT, PMT, video and audio streams, up to 3 Mbit/s;
    - 4:3 and 16:9 video format format detection, scaling to letterbox, center cut-out and SCART signalling.
- DVB-T [ETSI EN 300 744].
- Video on demand:
    - Interactive Video-on-Demand (IVOD) and Near Video-on-Demand (NVOD);
    - Protocol RTSP;
    - Verified compliance with leading video server suppliers.
- Security:
    - SSL version 3.0, 64 and128 bits;
    - PKI box login, encryption/decryption (Optional);
    - Macrovision copy protection ver. 7.01 (Optional).
- Graphics:
    - Computer graphics 24 bits/pixel RGB;
    - Resolution 720x576 pixels (PAL), 720x480 pixels (NTSC);
    - Video 24 bits/pixel RGB;
    - Picture-in-Graphics;
    - On Screen Display (OSD);
    - Alpha blending;
    - Color keying;
    - Graphics accelerator 2D;
    - Spatial - temporal deinterlacing using motion detection and estimation;
    - Flicker filtering of graphics.

While this STB supports CAS for encryption of the transmitted stream, the main constraint for streaming is that encrypted content has to be decrypted on the fly on client side (STB). Most popular STB's (Kreatel is not an exception) does not include DES/3DES hardware accelerators thus placing enormous amounts of load to the main CPU. In IPTV world the family of DVB related encryption/scrambling algorithms is dominant. DVB-CSA (DVB Common Scrambling Algorithm) is a video scrambling standard which is widely accepted in IPTV industry. Accelerators of these algorithms are implemented in hardware of Kreatel STB and the licensing costs are covered by STB provider. During research it was identified that an Axmedis Streaming client will have to be developed which builds an MPEG-TS decoder pipeline with an DVB-CSA integration element. In terms of DVB-CSA de/scrambler Control Words (CW) has to be exchanged in some manner. A possible solution could be to use only one CW (key) that would be sent to the user with AXMEDIS license.

Thus the streaming client pipeline has to include additional element - DVB-CAS CW exchanger. Efforts to develop such STB streaming client would have to be evaluated separately.
Server side implementation of stream protection is problematic also. DVB-CSA algorithms are protected by ETSI ETR 289 standard. The standard is open, but several conditions have to be met:
1) Licensee has to be "a conditional access systems provider, a conditional access designer, a conditional access subsystem manufacturer, a conditional access subsystem integrator or a descrambling component manufacturer." It must be evaluated whether any member or the consortium can be considered as a valid DVB-CSA license entity.
2) The licensing royalties for the standard are 1000EU for copyright holders plus 1000EU administrative fee. Because the algorithms are protected by NDA access to the scrambling code may be problematic due to expensive license costs and administrative delays.
If standard licensing turns out to be a non-issue, some source code of algorithm implementation was identified on the internet. Again, the development efforts to enhance the streaming with DVB-CSA scrambling on the server side would need to be evaluated separately during the next stages.
In addition, a number of other STB-related issues were identified during the analysis and research:

1. AXFW porting to Kreatel STB is complicated:
   - Kreatel development tools provide GNU C++ compiler 3.6 which is strict to C++ standard violations.
   - Some portions of AXOM violate C++ standards and does not compile with latest compilers
2. The AXMEDIS code has multiple C++ coding styles
   - It is very difficult to adapt headers to the C++ standard, since two coding styles are used. Intervention to AXFW source code and manual harmonization of coding styles is needed.
3. The basic AXOM library size is at least 35 MB, which is too large for embedded environment. Code optimization and removal of unnecessary parts will be required.

A number of working solutions were tested to address these issues, including efforts to analyse AXFW code porting to possibilities to Kreatel STB.

The AXSTB Player will be developed by porting AXMEDIS PC Player onto the Set-top-box. Functional requirements for the AXSTB Player are as follows:

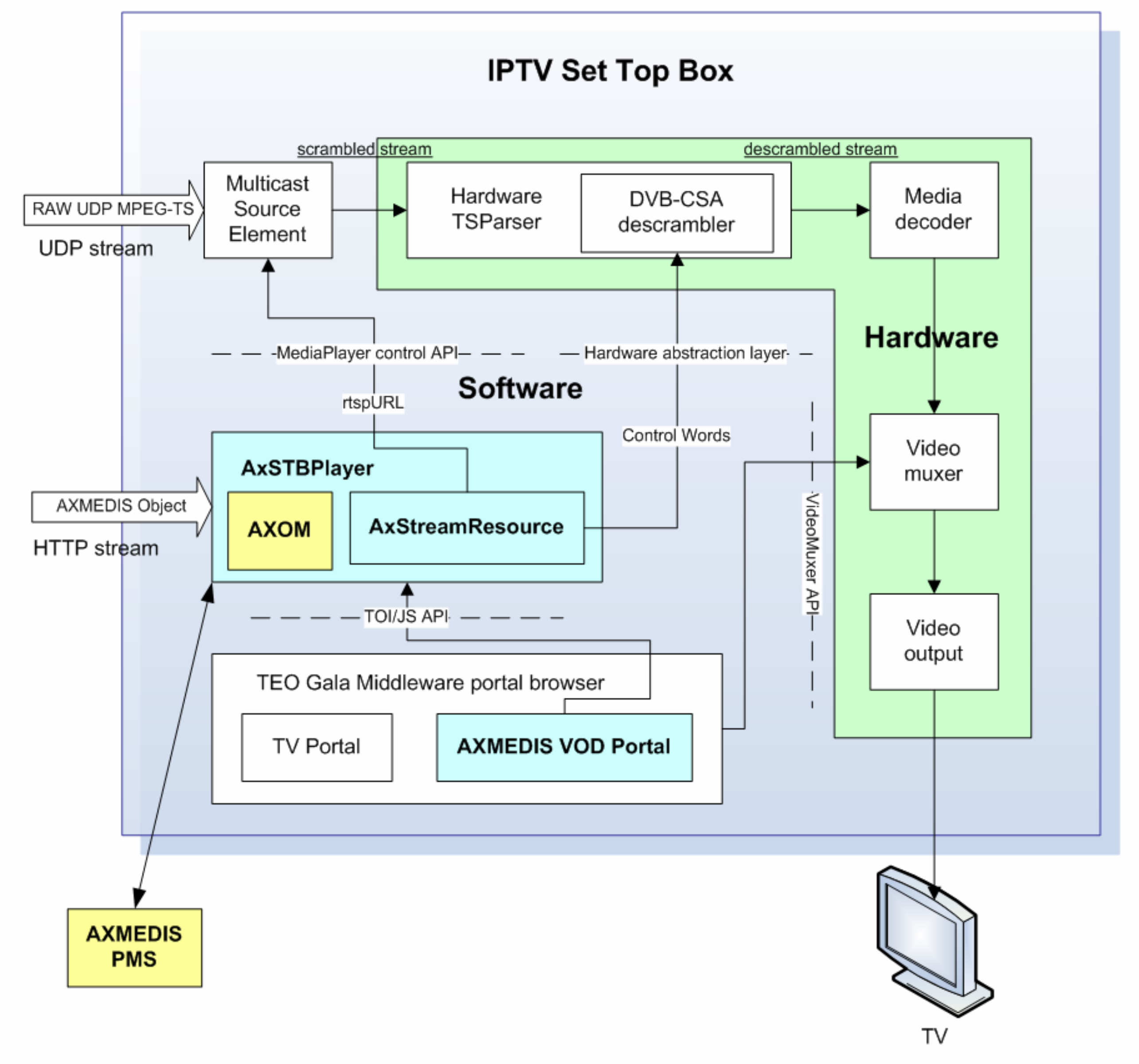
- Should have an attractive user interface;
- STB Remote control enabled user functionality;
- Should enable the user to Play, Stop, Pause and Seek the digital content being played;
- Digital formats to be supported by the AXSTB Player:
  - MPEG -2
  - MPEG -4.

AXSTB Player utilizes AXOM to access the AXMEDIS object residing in TEO AXDB by providing AXOID. In TEO AXDB the AXMEDIS object metadata and stream information (AxStreamResource) is stored and the MPEG-2 TS resources are excluded due to storage efficiency.
When AXSTB Player tries to access AxStreamResource in AXMEDIS object, AXOM protection processor is executed to deprotect the object according to the issued license. If the user has bought the object and has valid license, AxStreamResource is decoded from object and AXSTB Player gains access to the following information:

1. Elementary audio/video streams composing MPEG-2 Transport Stream
2. How to access MPEG-2 Transport Stream
3. Hardware DVB-CSA Descrambler Control Words for each Elementary Stream

Therefore AXSTB Player can initiate the streaming of AXMEDIS Object MPEG-2 TS resource other network towards STB. On the other hand, AXSTB Player has access to the hardware DVB-CSA descrambler via Hardware abstraction layer and can setup hardware to process required streams by providing adequate descrambling Control Words. After initiation of MPEG-2 TS streaming from VOD server, STB

starts receiving live scrambled video/audio stream. This stream is forwarded from multicast/unicast source element to DVB-CSA descrambler. Here the streams are descrambled using control words. The descrabled streams are fed to Hardware MPEG decoder (Media decoder) and the decoded video is multiplexed with VOD portal view and sent to video output of STB towards TV.
AXSTB Player is controlled by AXMEDIS VOD Portal which receives user's directions from remote control unit. In the picture below, presented is the generalized Kreatel STB architecture and it's modification to support playing of AXMEDIS Objects from VOD server.

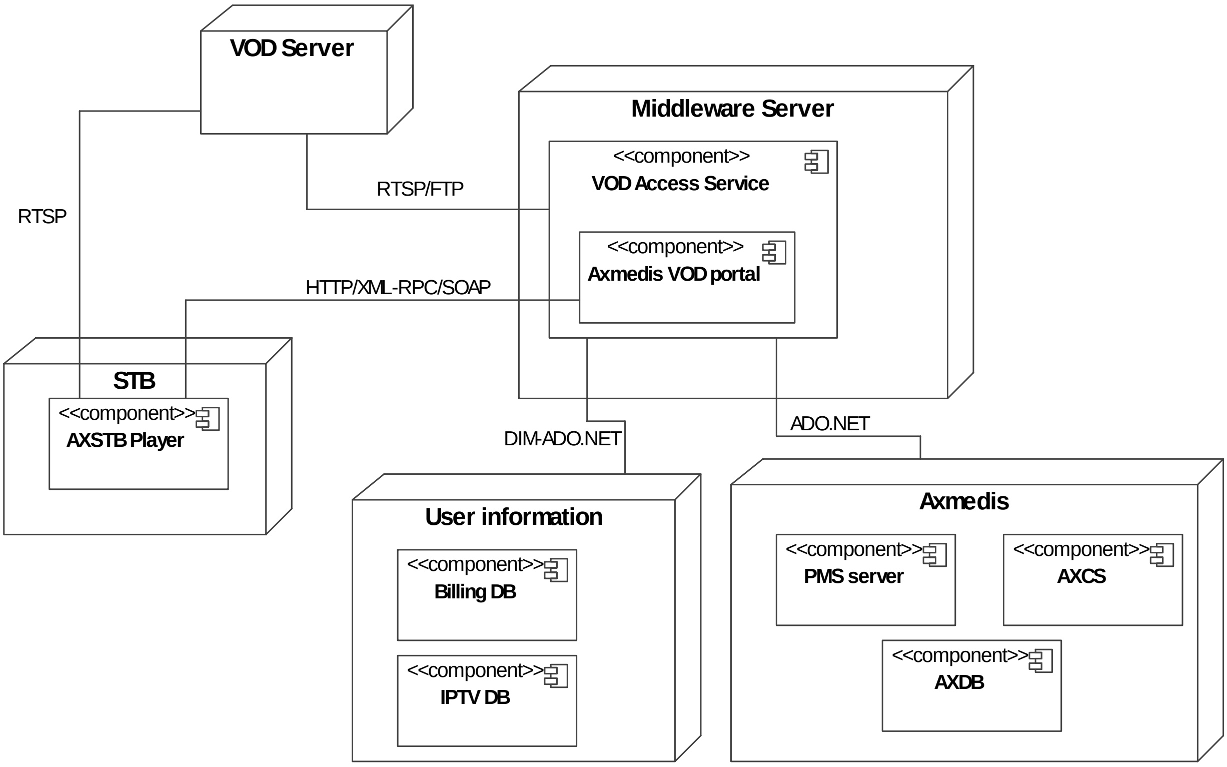


In AXSTBPlayer development these libraries are used:

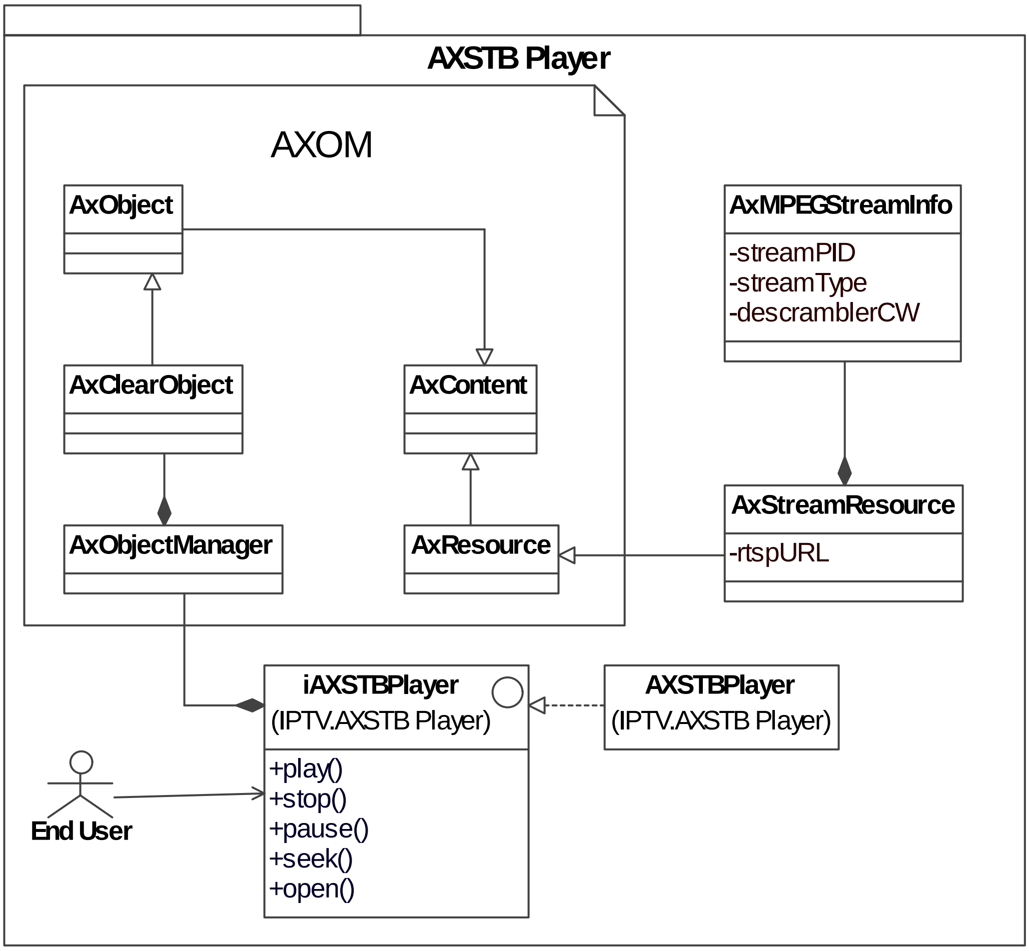
- gdk 1.2
- gtk 1.2
- glib 1.2
- gmodule 1.2
- X11 6
- Xext 6
- GtkIpc 3.3.1

- Ipc 3.3.1
- XmlParser 3.3.1
- Toi 2

The implementation strategy for AXSTB Player is presented in deployment diagram below. AXSTB Player will communicate with VOD Server using RTSP protocol. This protocol will be used for communication between VOD Access Service and VOD Server. VOD Access Service will be implemented in middleware server. VOD Access Service will communicate with user information databases (Billing DB and IPTV DB) by using DIM-ADO.NET protocol. ADO.NET protocol will be used for communication between VOD Access Service and AXMEDIS tools (PMS Server, AXCS, AXDB). AXSTB Player will use HTTP/XML-RPC/SOAP protocols for communicating with VOD Access Service.



AXSTB Player package is specified in detail in the presented AXSTB Player class diagram. In AXSTB Player package Player interfaces is specified. Player interface is used for playing streamed video from VOD server. Player interface use iAccessService interface from VOD Access Service package. iAccessService interface communicates with VOD server, Billing DB, IPTV DB, AXDB, and AXMEDIS PMS. AXSTB Player class diagram is presented below.



AXSTB Player utilizes AXMEDIS Object Model and Manager to access and play resources. The original AXMEDIS object from VRS is never decrypted in TEO VOD servers. The video content reaches client STB in scrambled and untouched form. In order to be able to decrypt the scrambled audio/video content, Player has to utilize AxObjectManager and protection processor to gain Control Words. Without control words it is impossible to gain access to scrambled stream data. This solution utilizes hardware to achieve max performance and AXOM to achieve max AXMEDIS DRM compliance.

5 Delivering Management and cache strategies (CLOSED)

5.1 Introduction

The broadcast distribution provides an efficient vehicle for delivering very large amount of digital content to a big number of end users. The availability of cheap mass storage devices on the client platform allows to experience new fruition paradigms that go far beyond the simple television model, providing an easy access to a large list of content that has been preventively downloaded.

The problem of selecting the appropriate content to be stored on the local disk arises. A manual solution, based on explicit download requests (like in PVRs), could be adequate for advanced users that intend to play an active role in controlling the client platform. However, in most cases, the availability of proactive filtering and caching algorithms may be the best solution for providing the end users with a satisfactory selection of content.

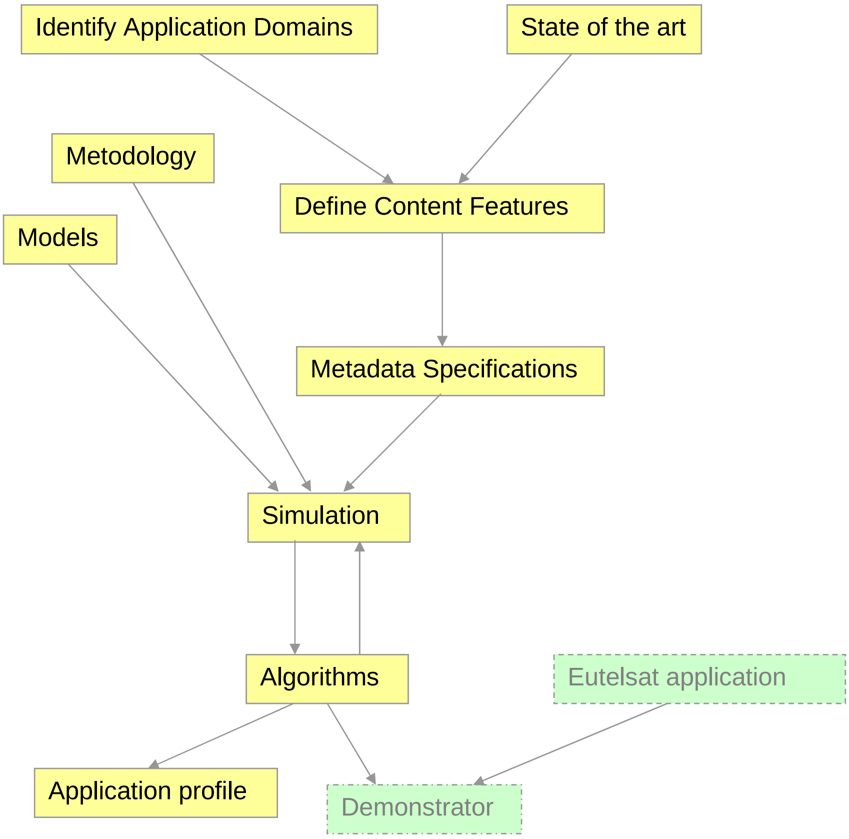
5.2 Objective

The objective of the present work is to identify and validate a distributed adaptation engine for the AXMEDIS application model "Cache-based distribution on iTV" (T4.8.2), described in section 18.2 of DE2.1.1a (User Requirements and use cases). This involves considering the different aspects of the content delivery chain: the optimisation of the content carousel, the client-side content filtering and the management of the client cache.

The main components of the recommendation system

In order to achieve this objective, the following actions will be followed:

- an analysis of the current development stage of Personal Video Recorders (PVRs), with specific focus on enabling technologies, business models, legal issues, impacts on viewers habits, etc.;
- an analysis of the state of the art of recommendation systems (algorithms for client-side content filtering, caching policies, user profiling techniques, etc.);
- the identifications of a set of content features required by recommendation algorithms in different application domains;
- an overall analysis of content description standards with the aim to specify a subset of AXMEDIS compliant metadata that enable an effective content personalization for different kinds of multimedia material;
- a definition of a valid methodology for testing and evaluating different recommendation systems for the "Cache-based distribution on iTV" application model;
- the specification of the recommendation algorithms that will enable the set up of the demonstrator of the "Cache-based distribution on iTV" application model.



Required actions for defining the recommendation algorithms

5.3 Current development of Personal Video Recorders

5.3.1 PVR general features

A Personal Video Recorder[1] (PVR) is a Set-Top Box with a hard disk that, thanks to the possibility to store the audio-visual streaming on a non-volatile media, enables new access paradigms for television content.

Although the AXMEDIS "Cache-based distribution on iTV" application model does not support a streaming distribution like in PVRs, both application environments involve similar issues, especially in user habits, but also as far as content filtering and cache management are concerned. Therefore an analysis of existing PVRs business models is important for the AXMEDIS "Cache-based distribution on iTV" application model.

PVRs provide many advantages. First of all, the possibility to record with no necessity of any physical support to be changed each time. Moreover, some PVRs with more than one tuner allow to record more than a single program at a time (or to view a program different from the one which is being recorded). A further advantage is the possibility to defer or pause the viewing of live television (the user can start the viewing while the program is still being recorded). Another relevant advantage is the availability of a rewind feature (a part of the hard disk is used to keep the recording of the last hour of the program currently on view, each time the user selects a new program, the PVR discards this memory in order to start recording the new channel). The possibility of registering at different quality levels allows the user to optimise the available space in the HD. A fast forward feature, available in deferred viewing, may be used to skip ads.

Beyond these basic features, PVRs offer also some important services that depend on the commercial types available on the market. A typical PVR offers some kind of search tools (e.g., by name of the program, by name of an actor, by keyword).

An Electronic Program Guide (EPG) is always available, although its level of effectiveness is variable. The importance of the EPG in the PVRs is particularly high not only for the great amount of available channels, but also for the possibility to set the recording on the hard disk of more than a program at a time. The most advanced EPGs report two weeks scheduling.

Another useful feature is the personalization of program recording (according to the user's preferences).

In the United States some PVRs have a broadband connection which allows the users to download videos also from the web to the hard disc. For this reason TV companies are organising websites to provide this kind of service as well; an example of this service in UK is provided by Telewest (the cable operator), which also created a personalization of the service [Bulkley, April 2004]

5.3.2 Current PVRs market

At present many types of PVRs are available on the market. Some of them are just set-top boxes with hard-disk recording facilities, other integrate hardware capabilities with some services (e.g. an advanced EPG, the possibility to control the PVR from the web, etc.). This latter group includes: Tivo (www.tivo.com), ReplayTV (www.replaytv.com), Sky Plus (the service offered by BSkyB in UK, website: www.skyplus.co.uk). There are also similar products for PC (e.g., ATI TV-Wonder Elite and Sony Giga Pocket), but they provide just the recording (on the hard disk of the PC) and VCR-like features.

TiVo (Television Input/Output)

TiVo service is only available in United States and UK (although the boxes are not longer sold in UK). TiVo is aimed at satisfy more technology expert people, rather than simply offering a better TV. TiVo users are generally PC users who prefer to use the typical PVR features, more than simply viewing live TV; for example, they are used to skipping almost all the advertisements [Bulkley, April 2004]. TiVo boxes are able to work both with cable or satellite equipment.

TiVo allows the users to remotely connect to the PVR, via a web browser (for example, from the office), and to set it to record a program.

Users can choose to switch on the "Suggestions" feature which enable the system to learn the user's preferences in order to propose a set of programs which are likely of interested for him/her. The Suggestions are based on the programs recorded by the user and on his/her opinion (thumb up/down) after viewing them.

[1] also known as Personal Digital Recorder (PDR)

Another personalization feature is the "Wish Lists", which allows the user to make a list of names or keywords about topics of interest (the name of an actor, the name of a singer, the title of a film, etc.), although it refers only to one user.

It is also possible to set the PVR in order to register a series of episodes (called "Season Passes" feature) keeping into account also last minute schedule changes.

The producers of TiVo chose to not include an automatic commercial-skip feature in order to avoid problems with content providers and advertisers. In fact, although the business model is above all based on subscription fees, advertising is still considered an important revenue.

For this reason recent TiVo PVRs have a new feature: generally users avoid a set of ads by stopping the live TV for a while and then fast forwarding up to the end of it; TiVo software shows a still picture (with a commercial ad) while the fast forward is taking place.

ReplayTV

Replay TV is a PVR service that works only in the United States, acting as the main TiVo antagonist. While TiVo is more oriented on personalising the TV experience, ReplayTV offers different features, such as providing a firewire output and room to room streaming. It had also two extra features that have been removed in the last release of PVRs with ReplayTV, due to legal issues:

1. the possibility to transfer shows to other ReplayTV units across the Internet (although it is still possible inside the local home network)
2. the automatic skipping of commercial advertisements (in any case, a manual skipping can be performed in the same way of all the other PVRs).

The main features of ReplayTV are the following: search by actor, director, title or subject; possibility to record every episode of a show; scheduling through the Internet; High Definition feature.

Some ReplayTV boxes reach a very long recording capacity (up to 320 hours).

Sky Plus

Sky Plus is the PVR service leader in UK which was first launched in October 2001. The kind of service offered by Sky Plus aims at providing an advanced television experience, so it is more targeted to the normal TV public. In fact, the typical Sky Plus user is primarily interested in live TV.

The top PVR of the series providing Sky Plus services was introduced on the market at the end of 2004. The new PVR, made by Thomson, has a 160 GB HD and costs 399 GBP (the previous PVRs had a 40 GB HD). This PVR provides also the possibility to set a PVR recording sending an SMS to a central hub which is able to program the PVR remotely [Nick Flaherty, 2005]. There are also other PVRs providing Sky Plus services which have lower features and costs. Due to an integration with NDS VideoGuard Conditional Access, Sky Plus contents are stored on the disk in an encrypted format (http://nds.com/pdfs/Sky_Digital_casestudy.pdf).

Sky Plus also allows to record a series of episodes with just one setting operation once for (the entire "Series link" feature).

Comparison table

	TiVo (USA)	ReplayTV (USA)	Sky Plus (UK)
Hours recording capacity	40 – 140	40 - 320	20/80
Box price	199.00 -299.00 USD	99.00 - 599.99 USD	89.00 – 299.00 GBP
Monthly Subscription fee	12.95 USD	12.95 USD	29.50 – 51.00 GBP
Product lifetime subscription	299.00 USD	299.00 USD	-

5.3.3 The future development of PVRs

PVRs are part of a world which is fast developing and which makes it hard to predict in which way. Generally speaking, future features are of the following kinds:

- Multiple-tuner boxes (for TV and for interactive services, so that it is possible to record a program and to see other two picture-in-picture, or recording more than a channel at a time), although twin-tuners are already quite common.
- Hybrid tuners with broadband, terrestrial, cable and satellite.
- DVD-RW alongside the PVR, integrated in the TV.

- Portable PVRs, the services available also to portable devices such as portable PCs and smart-phones.
- Personalised services (personalised advertising included).

5.3.4 The business model of PVRs

The Business model mainly relies on services (the subscription fee, which generally can be monthly or PVR's lifetime), rather then on the content delivered or on the boxes sold. Advertising also provides a significant revenue stream for many operators. Due to the easy way of skipping commercial ads (also during live TV), advertisers are recently starting to doubt about the efficacy of such a way of commercial promotions and are thinking to decrease its amount.

Another issue is related to the fact that digital Television offers a great number of channels which can be collected under the following four types:

general channels, which provide many genre of programs and are not targeted to any particular audience; *themed channels*, which are dedicated to only a genre (such as news, sport, etc.); *channels for specific viewer-groups*, which provide more then a genre but are targeted to a particular audience (such as, films, cartoons and other programs all dedicated to children, etc.); *niche channels*, which provide only a genre to a particular segment of viewers (such as, only cartoons for children, etc.).

Despite the variety of the available channels, for most of the viewers, iTV is still a passive experience very similar to the traditional analogue TV, and probably the situation will not change in the short period of time. The typical viewer uses to watch always the same subset of about 10 channels (although there are much more available) and to avoid interactive services. Another problem is that the number of available channels of different types has variegated the audience making advertising on each niche channel particularly expensive [Pagani 2003].

For all these reasons, at present advertisers producers are dealing with new strategies aimed at the creation of better commercial messages which use PVRs features, such as the possibility to download in the hard disc the trailer of a forthcoming film, rather then a simple announcement about it [Bulkley, April 2004].

To increase the PVR market, platform operators are always working on improving the service with more and better features. Also PVR features are growing fast while their prices are decreasing.

Issues (legal and others)

ReplayTV had encountered two legal issues: the possibility to transfer a show to another ReplayTv through the Internet without the ownership of the contents and the automatic advertising skipping.

Some users do not appreciate that *TiVo* is able to learn usage data from client platforms.

Watershed issues: a problem related with watershed is that a program recorded during the post-watershed time has also advertisements which are not suitable for children, so parents have to pay attention in skipping them [Bulkley, April 2004].

Impact on the users and on the market

Although PVR users are generally quite satisfied about the service, the market is not going very well. For example, TiVo in UK is still present as a service, but TiVo boxes are not available to buy any more.

As for many other innovative technologies, most of the users actually do not use all the available features.

Platform operators are shifting towards the marketing of PVRs:

- In Germany, Pace has stipulated an agreement to supply PVRs to Premiere
- In UK Telewest has announced a forthcoming PVR with top features (a four-tuner PVR with 160 GB HD plus a connector for an extra hard-drive)

5.4 State of the art of recommendation systems

5.4.1 User Profiling

Many recent research activities are related to the problem of performing recommendations for TV programs as well as for web and mobile services. The target of these systems is the maximisation of the user satisfaction by providing selected contents (or a list of suggested contents) which are compliant to his/her specific preferences.

A common feature of most of them is the presence of an initial user profile which is explicitly given by the user (Blanco-Fernandez 2004, Burke 2002, Goren-Bar 2004, Kang 2004, Kurapati 2001, Middleton 2001, Munchurl 2004, Pappas 2003, Van Setten 2003, Wei-Po 2003), and often completed by the analysis of the behaviour of the user (Blanco-Fernandez 2004, Goren-Bar 2004, Kang 2004, Kurapati 2001, Middleton 2001, Munchurl 2004, Nakamura 2000, Pappas 2003, Wei-Po 2003). Some applications are user-based in which they consider above all the demographic information about the user (Kurapati 2001) or the user behaviour (Nakamura 2000). Other methods are content-based, considering mainly the features of the contents to be provided (Goren-Bar 2004, Middleton 2001, Nakamura 2000). Some are called “knowledge-based” because they use techniques of the knowledge management and the semantic web, such as ontology to manage the resources in a more efficient way (Burke 2002, Middleton 2001), or data mining to discover new information (Schafer 2004).

Some researchers consider also the importance of an explicit feedback related to the recommendation system results (Blanco-Fernandez 2004, Kurapati 2001, Middleton 2001) in order to increase the adaptive feature of the system (although, during the testing activity in Kurapati 2001, the way to get the user’s feedback was just a diary, not a technical one).

An important aspect is related to the problem that it is difficult to reach a high level of efficacy by using just a single technology for all the situations. In fact, each method has an acceptable behaviour in relationship with some aspects, but some lacks in others; an interesting classification is provided in Burke 2002 where different methods are described among with the many ways of combining more than one recommendation in order to compound an hybrid recommendation system. A typical way to build an effective hybrid recommendation system is to consider a collaborative system together with a user-based (Blanco-Fernandez 2004), a content-based (Goren-Bar 2004, Middleton 2001, Nakamura 2000) or a knowledge-based (Burke 2002, Schafer 2004).

Common algorithms used in recommendation systems are Bayes (Blanco-Fernandez 2004, Kurapati 2001, Nakamura 2000), decision trees (Kurapati 2001), and k-Nearest Neighbour (Middleton 2001, Wei-Po 2003). Bayes techniques are considered particularly suitable because they are probabilistic based and allow to work with uncertain or incomplete knowledge. More specifically, when new evidence is known, Naïve Bayesian networks easily allow to update the inference network. Bayesian networks are used both for collaborative and for content-based systems.

K-Nearest neighbour algorithms represent the items as vectors of features; the vector distance is used to classify new items. They are suitable working with fast growing and changing items characterised by many features.

Decision trees are also used for adaptive learning systems, although they need to work with complete data and have a risk of becoming too large.

5.4.2 Cache Management

An interesting application of cache management is provided in Nakamura 2000, where @RandomTV, a PC-based digital video home server is presented. @RandomTV is a hybrid recommendation system for TV programs. The problem of the portion of hard disk dedicated by the user to the application is solved with an extension of the knapsack problem. It is reasonable to consider the cache management as a knapsack problem in which there is a set of items of a particular size and value which have to be put in a limited size, under the condition of the maximisation of the total value. In the case of a recommendation system, such as @RandomTV, the value of the items is the probability that the item will be selected and seen by the user. For the @RandomTV the authors have expanded the knapsack problem introducing the time variable.

5.5 A possible approach

At this point of the research activity it is possible to provide some general considerations about the main features of the client application.

5.5.1 User profiling and content filtering

The user profiling will be performed on client side but shall be connected to the AXMEDIS broadcasting server in order to use the information stored in a table reporting all the user profiles. **The user profiles will be XML files whose structure can be briefly described as a set of couples "element-value".**

It would be better to implement a hybrid recommender system, compound by a Collaborative and a Knowledge-based system.

A critical aspect of hybrid algorithms is the different techniques used to merge them. A possible merging is based on a weighted criteria, where the weight can be proportional to the probabilities of the contents to be chosen by the user. In this case, the **weights given to the collaborative and to the knowledge-based systems should vary dynamically**, depending on the status of the system and on the profile of the specific user. In fact, during the **system first period (start off)**, the database of other users preferences is not very meaningful, so the algorithm will mostly consider the explicit profiles provided by the user (and so a higher weight is associated to the knowledge-based part). This criterion should also be adopted for users with peculiar preferences. On the other hand, at **system run time,** and for most users, a certain amount of similar user profiles will be available and the algorithm should give a higher weight to the collaborative recommender system; this criteria should also be adopted for new subscribers, who can not have already a sufficient usage history. An example of how to define a user profile and the usage history is provided by Middleton 2001, where each user profile is expressed by a vector of features.

5.5.2 Algorithms for the user profiling and content filtering

Both the collaborative and the knowledge-based algorithms can be implemented as Naïve Bayes classifiers (for the collaborative see, for example, Blanco-Fernandez 2004; for the implicit user profile see, for example, Kurapati 2001).

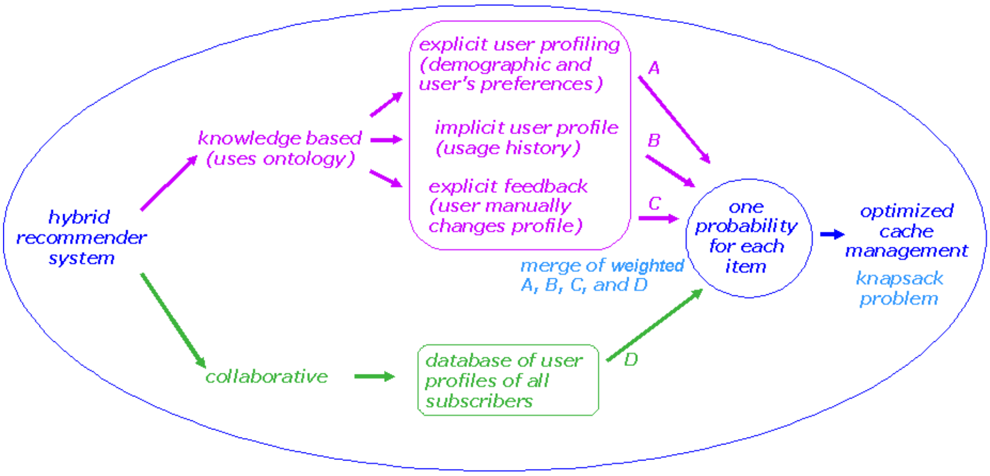
In any case the Collaborative Recommender is suggested not only in order to better deal with the typical "start-up" problem ("new user" and "new item" problems) but also to discover "user niches" (related to particular contents preferred by similar users). The main problem with Collaborative Recommenders is that once a user profile is recorded, it is not very easily changed. This is one of the reasons to adopt hybrid recommender systems. Some different considerations are related to the knowledge-based part of the system. It could be based on two different ontologies: one for the content classification and the other for the user profiles. The first one shall be appositely built for the metadata of the content description. The second one shall be compliant with the UsageHistory DS and the User Preference DS, defined in the MPEG-7 MDS standard.

The usage history keeps a record of the behaviour of the user through the GUI of the service. A different score will be given to each item proposed in the cache memory accordingly to the operations performed by the user. When an item in the cache is selected to be seen by the user, all the super classes of that content in the ontology gain a share (for example, 50% for the super class, 25% for the next super class, and so on). In this way the ontology allows to record more information about the implicit preferences of the user (Middleton 2001).

5.5.3 Cache management

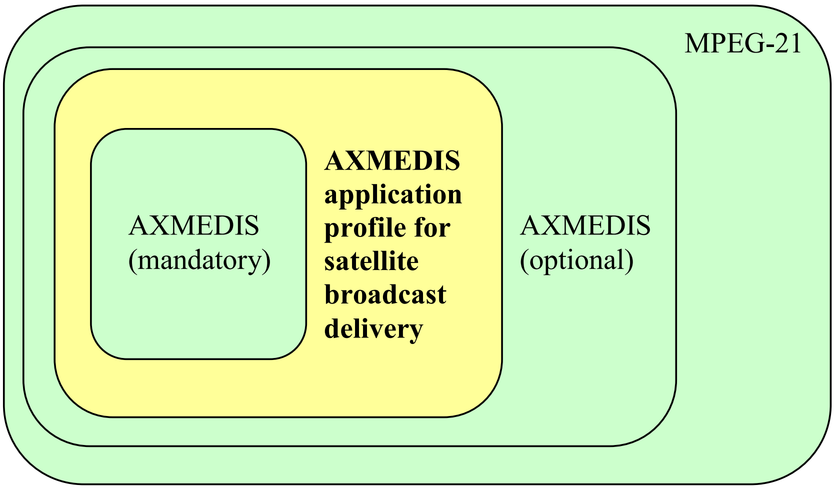
The cache management is a typical "**knapsack problem**" where the *knapsack capacity* is the cache size, while the *value* of each item to be put in the *knapsack* is the probability that the user will select it (will watch the content). In the specific AXMEDIS client application, the knapsack problem is binary (each item can only be included or not) and bounded (because of the finite number of items to be considered). An interesting extended knapsack problem for an *automatic recording agent for digital video server* was presented by Nakamura 2000. We intend to implement it in our tool, a part for the correction to be applied in order to keep in account the cases in which there is little information and so the data are not reliable. For these cases it would be better to consider a probability calculated in a different way, instead of correct it.

A Greedy algorithm could be used to fill in the cache memory: the items are sorted by probability (from the highest to the lowest); at each loop a new item is added only if its size does not exceed the available space; if the remaining space is smaller than the size of all the single remaining contents, the loop ends immediately. At the beginning of each process, the cache could be emptied. Alternatively the items which have not been watched by the user, and which have a probability greater than all the new items, could be left in the cache; in all the other cases they will be removed (and stored again, if necessary).
The following picture provides an overall scheme of the possible approach.


explicit user profiling (demographic and user's preferences)
implicit user profile (usage history)
explicit feedback (user manually changes profile)
knowledge based (uses ontology)
hybrid recommender system
A
B
C
D
one probability for each item
optimized cache management
knapsack problem
merge of weighted A, B, C, and D
collaborative
database of user profiles of all subscribers

5.6 Content description standards

A key requirement for designing a recommendation system based on content filtering is the choice of a suitable metadata scheme. Many content description standards exist, addressing specific application needs. Dublin Core (DCMI, 1999), a simple and widely adopted metadata scheme based on a small set of attributes and encoding schemes, is quite generic and mainly aimed at describing generic resources. MPEG-7 (ISO/IEC 185938), specifically targeted to multimedia content, provides detailed formatting information and fine-grained descriptions of the structural, and low-level audio, visual and audio-visual features. Within the domain of digital television, DVB-SI (ETSI EN 300 468) defines a small set of programme-related metadata (title, start time, duration, description, parental rating, genre) for constructing interactive EPGs. However, being only a minimal subset of DVB-SI metadata mandatory, its full potential is far from being achieved. TV-Anytime (ETSI TS 102 822), based on Mpeg-7, represents a necessary step towards a more complete programme description addressing the increasing demanding needs of PVRs platforms.
AXMEDIS Objects encapsulate metadata in MPEG-21 descriptors (AXMEDIS DE3.1.2A). All metadata sets (except AXInfo, that is specific to AXMEDIS compliant tools) are accessible from MPEG21 terminals, even for protected AXMEDIS objects, allowing to define specific metadata profiles. AXMEDIS objects are required to provide Dublin Core metadata. MPEG-7, along with other XML-encoded metadata schemes, are optionally supported by Axmedis objects.
The present analysis is aimed at identifying the minimal set of metadata required for setting up a recommendation system for Axmedis satellite distribution. Since this metadata set is likely to be larger than the mandatory subset provided by Dublin Core, a specific application profile will be defined within the scope of the AXMEDIS “Cache-based distribution on iTV” application model. The final demonstrators shall be compliant with this profile.


MPEG-21
AXMEDIS (mandatory)
AXMEDIS application profile for satellite broadcast delivery
AXMEDIS (optional)

Although the satellite distribution can be used to carry any kind of AXMEDIS objects, a delivery paradigm combining the push distribution with the client-side filtering is best suitable to audio-visual content, for different reasons: (1) audio-visual content can be fully consumed in a passive way, without requiring an interactive communication with the provider; (2) a one-to-many distribution is very effective for the increasingly bandwidth demanding audio-visual content.

Therefore the following application domains will be covered: movies, music, TV programs. Possible extensions to non-audio-visual domains (such as e-books) can be considered as well.

In order to determine the set of features required as sources for the possible recommendation systems, different real-world description tags have been considered for each of the above listed domains. A common set of high-level features has been determined and an analysis of a possible mapping to DC or Mpeg-7 has been carried out. Low-level features (such as time-domain or frequency-domain audio features), although can be easily extracted in an automatic way, are harder to correlate to user preferences and have not been considered in the scope of the present work.

The following sources has been considered for domain-specific descriptors:

- as far as movies are concerned, a good information source is the Internet Movie Database (IMDb), providing detailed information on over 400.000 films, through a rich set of high-level description tags;
- as far as music is concerned, ID3, although not part of the ISO/IEC 11172-2 Layer 3, has become the de-facto description format for MP3 files; in particular, ID3v2.3.0 provides a rich set of high level descriptors for music content;
- as far as TV programs are concerned, TV anytime provides a very detailed set of description schemes for TV content;

For each domain-specific descriptor, the suitability to different recommendation techniques has been evaluated, on the basis of the data-oriented classification defined by Burke 2002[2].

The following table summarises some considerations about the suitability of the domain-specific descriptors as input to the recommendation algorithm.

Descriptors			Recommendation algorithm suitability	
IMDb	**ID3v2.3.0**	**TV-Anytime**[3]	**level**	**Recommendation technique**

[2] Co=collaborative, Cb=Content-based, De=Demographic, Ut=Utility-based, Kb=Knowledge-based

[3] TV-Anytime metadata are reported as XPath expressions, where the path expression // stands for: TVAMain/ProgramDescription/ProgramInformationTable/ProgramInformation

Descriptors			Recommendation algorithm suitability					
(Movies)	**(Music)**	**(TV programs)**		**Co**	**Cb**	**DE**	**UT**	**Kb**
ID	Unique file identifier	Content Reference ID (Program CRID or GroupCRID)	●	√		√		√
Title	Title/Songname/Content description	//BasicDescription/Title	●	√		√		√
aka	-	//BasicDescription/Title/@xml:lang	●	√		√		√
-	Subtitle/Description refinement	//BasicDescription /Title [@type=”opusNumber”]	●	√		√		√
Year	-	//BasicDescription /CreationCoordinates/CreationDate	●●	√	√	√	√	
-	Date	//BasicDescription /ReleaseInformation/ReleaseDate	●●	√	√	√	√	
Genre(s)	Content type	//BasicDescription /Genre	●●●	√	√	√	√	√
-	Content group description	-	●	√	√	√	√	√
Plot keywords	-	//BasicContentDescriptionType/Keyword	●	√	√	√	√	√
Director	-	//BasicDescription/CreditsList/ CreditsItem[@role=”Director”]	●●	√		√		√
-	Lead artist(s)/ Lead performer(s)/ Soloist(s)/ Performing group	//BasicDescription/CreditsList/CreditsItem[@role= ”Performer”]	●●	√		√		√
-	Orig.artist(s)/ performer(s)		●	√		√		√
Writer(s)	-	//BasicDescription/CreditsList/CreditsItem[@role=”Author”]	●●	√		√		√
	Composer(s)	//BasicDescription/CreditsList/CreditsItem[@role=”Composer”]	●●	√		√		√
-	Lyricist(s)/Text writer(s)	//BasicDescription/CreditsList/CreditsItem[@role=”Lyricist”]	●	√		√		√
-	Orig. lyricist(s)		●	√		√		√
Producer(s)	-	//BasicDescription/CreditsList/CreditsItem[@role=”Producer”]	●	√		√		√
Distributor(s)	Publisher	//BasicDescription/CreditsList/CreditsItem[@role=”Distributor”]	●	√		√		√
Cast	-	//BasicDescription/CreditsList/CreditsItem[@role=”Actor”]	●●	√		√		
-	Band/Orchestra/Accompaniment	//BasicDescription/CreditsList/CreditsItem[@role=”Orchestra”]	●	√		√		
Runtime	Length	//BasicDescription /Duration	●	√	√	√	√	√
Country	-	//BasicDescription/CreationCoordinates/CreationLocation	●●●	√	√	√	√	√
Language	Language(s)	//BasicDescription /Language	●●●	√	√	√	√	√
Color / B&W	-	//AVAttributes/VideoAttributes/Color	●	√	√	√	√	√
Sound mix	-	//AVAttributes/AudioAttributes/MixType	●	√	√	√	√	√
Certification	-	//BasicDescription /ParentalGuidance	●●●	√	√	√	√	√
-	Album/Movie/Show title	//BasicDescription /Title [@type=”albumTitle”]	●	√		√		√
-	Orig. album title	-	-					
-	Track number	-	-					
-	Playlist delay	-	-					
-	BPM (Beats per minute)	-	●●	√	√	√	√	√

Notes:

Suitability level : ●●● very suitable, ●● suitable, ● possibly suitable, - unsuitable

The metadata identified in the previous table shall be mapped to a unique description scheme supported by AXMEDIS objects. The following scheme suggests a possible mapping to Dublin Core and to MPEG-7 Multimedia Description Schemes[4].

[4] ISO/IEC 15938-5 (Mpeg-7 part 5)

Content-specific descriptors			**Possible mapping to DC and MPEG-7**	
IMDb (Movies)	**ID3v2.3.0 (Music)**	**TV-Anytime[5] (TV programs)**	**Dublin Core[6]**	**MPEG-7 (MDS)[7]**
ID	Unique file id	Content Reference ID (Program CRID or GroupCRID)	identifier	UniqueID
Title	Title/Songname/ Content description	//BasicDescription/Title	title	//CreationInformation/ Creation/Title
aka	-	//BasicDescription/Title/@xml:lang	title/ alternative	//CreationInformation/ Creation/Title/@xml:lang
-	Subtitle/Description refinement	//BasicDescription /Title [@type=”opusNumber”]	title/ alternative	//CreationInformation/ Creation/Title [@type =”opusNumber”]
Year	-	//BasicDescription /CreationCoordinates/CreationDate	date/created	//CreationInformation/ Creation /Date
-	Date	//BasicDescription /ReleaseInformation/ReleaseDate	date/available	//CreationInformation/ Classification/Release/@date
Genre(s)	Content type	//BasicDescription/Genre	subject	//CreationInformation/ Classification/Genre
Plot keywords	-	//BasicDescription/Keyword	subject	//CreationInformation/ Classification/Subject
Director	-	//BasicDescription/CreditsList/ CreditsItem[@role=”Director”]	-	//CreationInformation/Creation/Creator/Role[Name = “Director”]
-	Lead artist(s)/Lead performer(s)/ Soloist(s)/Performing group	//BasicDescription/CreditsList/ CreditsItem[@role=”Performer”]		//CreationInformation/ Creation/Creator/Role[Name = “Performer”]
Writer(s)	-	//BasicDescription/CreditsList/ CreditsItem[@role=”Author”]	creator	//CreationInformation/ Creation/Creator/Role[Name = “Author”]
	Composer(s)	//BasicDescription/CreditsList/ CreditsItem[@role=”Composer”]		//CreationInformation/ Creation/Creator/Role[Name = “Composer”]
Producer(s)	-	//BasicDescription/CreditsList/CreditsItem[@role =”Producer”]		//CreationInformation/ Creation/Creator/Role/[Name = “Producer”]
Distributor(s)	Publisher	//BasicDescription/CreditsList/CreditsItem[@role =”Distributor”]	publisher	//CreationInformation/ Creation/Creator/Role/[Name = “Distributor”]
Cast	-	//BasicDescription/CreditsList/CreditsItem[@role =”Actor”]		//CreationInformation/Creation /Creator/Role[Name = “Actor”]
Runtime	Length	//BasicDescription/Duration	format/extent	//MediaTime/MediaDuration
Country	-	//BasicDescription/CreationCoordinates/CreationLocation		//CreationInformation/ Creation/ CreationCoordinates/Location

[5] TV-Anytime metadata are reported as XPath expressions, where the path expression // stands for: TVAMain/ProgramDescription/ProgramInformationTable/ProgramInformation

[6] DC elements refinements are defined in DCMI Metadata Terms (http://dublincore.org/documents/dcmi-terms/)

[7] MPEG-7 are reported as XPath expressions, where the path expression // stands for: Mpeg7/Description/MultimediaContent/*

Content-specific descriptors			**Possible mapping to DC and MPEG-7**	
IMDb (Movies)	**ID3v2.3.0 (Music)**	**TV-Anytime[5] (TV programs)**	**Dublin Core[6]**	**MPEG-7 (MDS)[7]**
Language	Language(s)	//BasicDescription/Language	language	//CreationInformation/Classification/Language
Color / B&W	-	//AVAttributes/VideoAttributes/Color		//MediaInformation/MediaProfile/MediaFormat/VisualCoding/@colorDomain
Sound mix	-	//AVAttributes/AudioAttributes/MixType		//MediaInformation/MediaProfile/MediaFormat/AudioCoding/Presentation
Certification	-	//BasicDescription/ParentalGuidance	Audience	//CreationInformation/ Classification/ ParentalGuidance
-	Album/Movie/Show title	//BasicDescription /Title [@type=”albumTitle”]		//CreationInformation/ Creation/Title [@type=”albumTitle”]
-	BPM (Beats per minute)[8]		-	-

News is another kind of content which would be very strategic to deliver in a personalised environment. In order to select personalised news by subject, data, anchorman, location, duration, etc., the following subset of TV anytime metadata is required. A possible mapping to MPEG-7 MDS is shown as well.

TV-Anytime[9] (News)	**Possible mapping to MPEG-7[10] (News)**
Content Reference ID (Program CRID or GroupCRID)	UniqueID
//BasicDescription/Title	//CreationInformation/ Creation/Title
//BasicDescription /CreationCoordinates/CreationDate	//CreationInformation/ Creation /Date
//BasicDescription/CreationCoordinates/CreationLocation	//CreationInformation/ CreationCoordinates/Date/Location
//BasicDescription/Duration	//MediaTime/MediaDuration
//BasicDescription/Genre	//CreationInformation/ Classification/Genre/ [Name=”Pure information”]
TVAMain/ClassificationSchemeTable/ClassificationScheme/[@uri=”urn:tva:metadata:cs:IntentionCS:2004”]	//CreationInformation/ Classification/Purpose/ [Name=”Information”]
TVAMain/ClassificationSchemeTable/ClassificationScheme/[@uri=”urn:tva:metadata:cs:FormatCS:2004”]	//CreationInformation/ Classification/Form[Name=(“Bulletin” or “Sport news”)]
//BasicDescription/CreditsList/CreditsItem[@role=(“Anchor” or “Reporter” or “Interviewer”)]	//CreationInformation/Creation /Creator/Role/[Name= (“Anchor” or “Reporter” or “Interviewer”)]/
//BasicDescription/Language	//CreationInformation/Classification/Language
//BasicDescription/Keyword	//CreationInformation/Classification/Subject

The following of the present work will assume that the all MPEG-7 metadata listed in the above tables will be available. Filtering and caching algorithms of the “Cache-based distribution on iTV” application model” may attribute different weights to each metadata tag. Extra requirements on metadata may arise from the “Cache-based Personalised Content Distribution” application model, described in section 18.9 of DE2.1.1.

[8] BPM is actually a low-level feature, that should be mapped to MPEG-7 Audio

[9] TV-Anytime metadata are reported as XPath expressions, where the path expression // stands for: TVAMain/ProgramDescription/ProgramInformationTable/ProgramInformation

[10] MPEG-7 are reported as XPath expressions, where the path expression // stands for: Mpeg7/Description/MultimediaContent/*

5.7 Methodology and tools

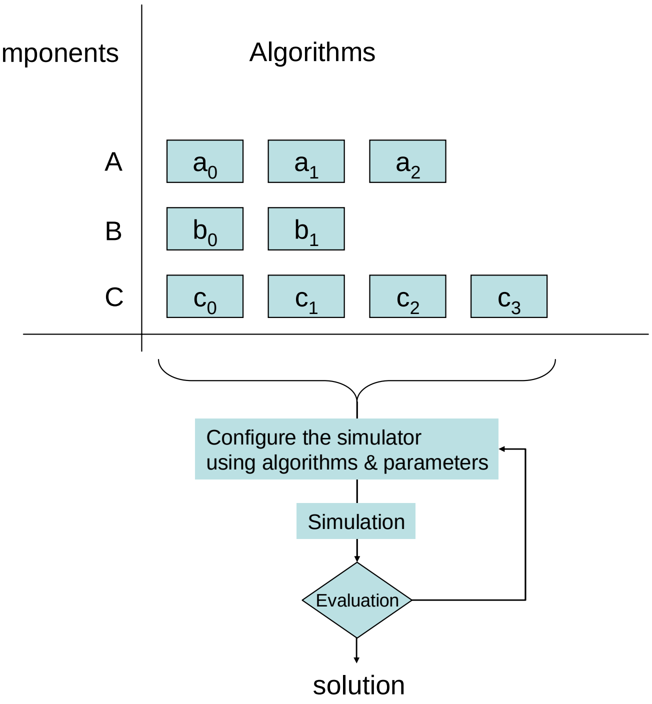
5.7.1 Methodology

In order to identify and validate a distributed adaptation engine for the AXMEDIS application model "Cache-based distribution on iTV" (T4.8.2), described in section 18.2 of DE2.1.1a (User Requirements and use cases), a simulation-based approach will be used. In particular:

- a software simulation environment, simulating the main components of the AXMEDIS application model "Cache-based distribution on iTV" will be built;
- for each component of the distributed adaptation engine a set of candidate algorithms will be chosen, as described in section 4.7, and a simulation module will be built for each of them;
- a set of measurement criteria for evaluating the simulation results will be defined (for instance, the rate of successful user choices could be chosen as a measure of the quality of a given solution).

The simulation will be carried out in the domain of a broadcast movie distribution service. The behaviour of a significant number of users interacting with this service will be simulated as well, using a behaviour model statistically compliant with the results of available surveys.

By repeating the simulation for different combinations of the candidate algorithms and/or simulation parameters, it will be possible to evaluate different possible solutions for the distributed adaptation engine.



5.7.2 Simulation tool

The purpose of the simulation tool is to provide an environment for evaluating the best algorithms for a distributed adaptation engine to be used in the AXMEDIS application model "Cache-based distribution on iTV". Therefore, a simplified approach will be adopted, leaving out all those details that are not directly related to the algorithmic aspects (e.g. transport over DVB, player, etc.).

A time-based simulation model will be used, organised as follows:

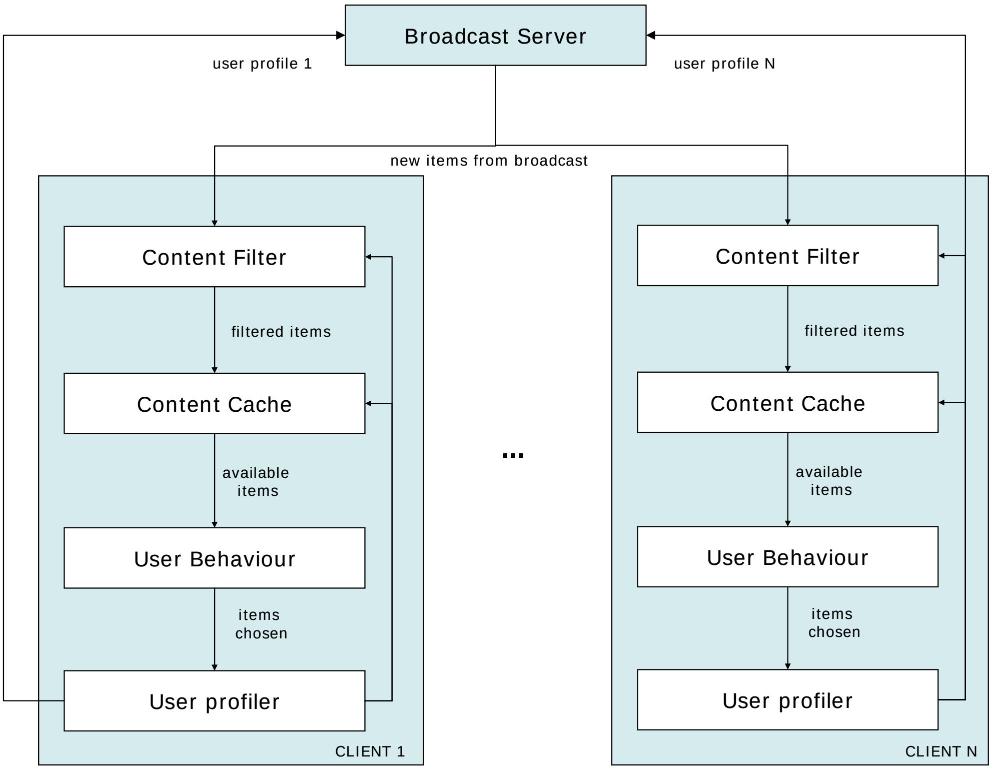
1. the simulation period [t_o, t_N] is split into N equal intervals starting at instant t_j, j=0, N-1;

2. the system is decomposed in N components, i=0,…,N-1, each component having an output vector Out(C_i) and an (optional) input vector In(C_i);
3. the simulation is carried out according to the following pseudo-code:

```
time = $t_0$
delta_t = ($t_N$-$t_0$)/N
repeat
        for all $C_i$
                simulate $C_i$, using inputs In($C_i$)
                save simulation outputs Out($C_i$)
        for all components $C_i$
                update inputs In($C_i$) according to saved simulation outputs Out($C_i$)
        time = time + delta_t
until time=$t_N$
```

5.7.2.1 Architecture

The following scheme outlines the general architecture of the simulator.



5.7.2.2 Components

Broadcast Server

In the simulation environment, the term Broadcast Server identifies all the server-side actions targeted to select and to deliver a set of Axmedis objects on a broadcast channel.

In order to simulate a broadcast movie delivery service, the selection of the objects to be delivered shall be done from a pool of items. The database provided by **MovieLens** (www.movielens.umn.edu) has been chosen for this purpose. MovieLens is a survey built by the GroupLens Research group of the dept. of Computer Science and Engineering of the University of Minnesota. MovieLens data have been collected by the ratings of volunteer users of a web-based movie-recommender system and it is compound by three textual files:

- information about 3.883 movies (id, title, year of production, and one or more than one genres)

- information about the 6.040 volunteer users (id, gender, age, and occupation)
- information about the 1.000.209 ratings (id of the user, id of the movie, and rate in the range 1-5)

The simulation activities only require metadata, not the actual resources. So using the MovieLens database as a source for building the pool of items suitable to be delivered in broadcast in the carousel is quite a sensible choice. The possibility of using other available databases can be considered as well.

The broadcast server is simulated by building a carousel of items, each one containing a film, and delivering these items through a broadcast carousel together with the corresponding resources. Both the algorithm construction and the delivery shall be done according to an user-selectable algorithm.

Content Filter

The client-side content filter is one of the key components of the adaptation system. It shall decide whether a new item coming from the carousel shall be ignored or shall be stored in the cache for future use. The choice of the filtering algorithm is fundamental.

The simulation shall test and evaluate different kind of algorithms in order to identify the best criteria of content filtering.

Cache management

The client cache is another key component of the adaptation system. The cache algorithm shall decide which items (and resources) should be kept in the cache and which should be freed in order to create the space required for caching new incoming items.

The simulation simply models the cache as a list of items associated with some information useful for managing the cache (frequency of access, latest time of access, age of the item, etc.).

User behaviour

The behaviour of a group of users interacting with the movie delivery service shall be simulated. This involves, for each user, simulating the process that leads to the decision whether or not to watch a particular title.

Actually, this decision process is assumed to go at least through two subsequent steps, each one involving a decision on its own:

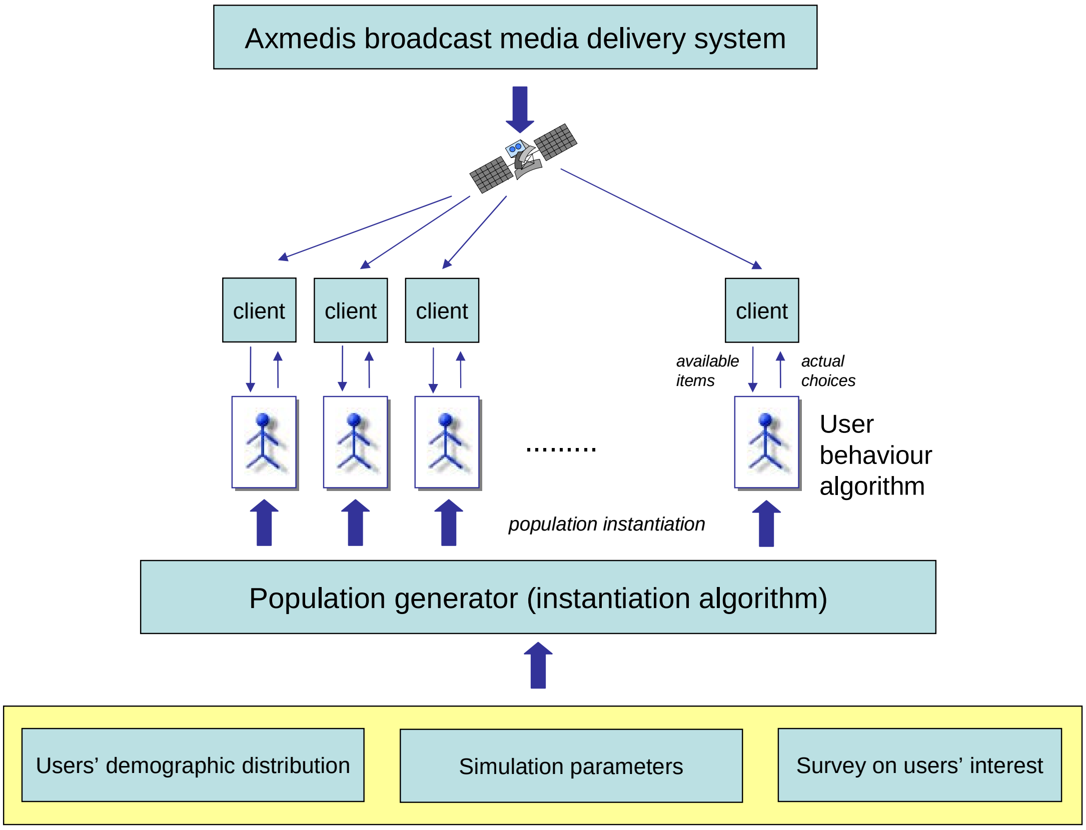
1. decide whether to browse the list of available titles, or do something else;
2. decide whether to watch a particular title, or do something else.

A third decision step may be present, involving deciding whether to leave the client terminal on, so that the cache can be updated from the carousel, or to turn it off.

All the above decision shall be simulated according to a given algorithm and may depend, in general, on time, date, user demographic profile, usage history, etc.

The simulation requires the instantiation of a population of users, according to a given demographic distribution and to plausible users’ interests, that can be obtained from some available survey (e.g. MovieLens). Therefore, a population instantiation algorithm shall be provided. The user behaviour simulation algorithm and the population instantiation algorithm strictly depend each other, so they will be provided together as whole.

The possibility to simulate a group of users belonging to the same household shall be provided as well.


Axmedis broadcast media delivery system
client
client
client
client
available items
actual choices
....
User behaviour algorithm
population instantiation
Population generator (instantiation algorithm)
Users' demographic distribution
Simulation parameters
Survey on users' interest

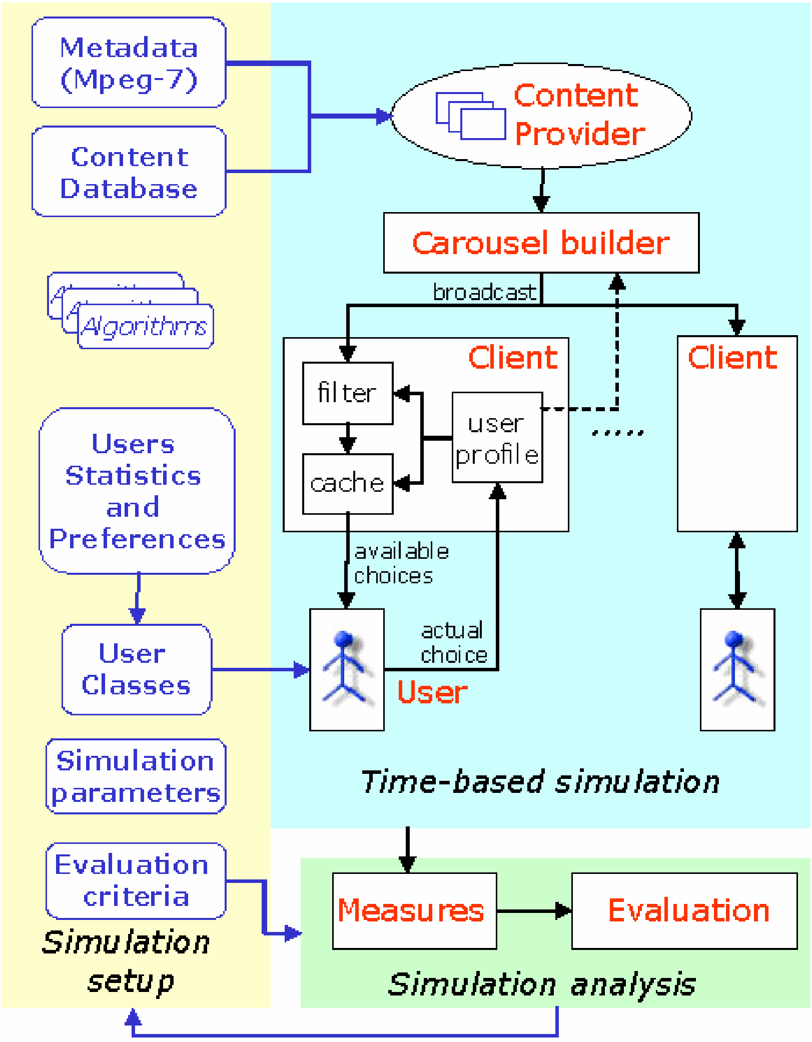
User profile

At simulation start time, the users' profiles are obtained by an analysis of the data available in the file about the ratings of the MovieLens survey. These profiles shall be changed after the simulation of the users' choices.

5.7.2.3 Usage

In order to implement a suitable tool for the research purpose, a working environment was necessary to allow the evaluation of the different kinds of algorithms related to the previously mentioned component.

The working environment is made of a set of parameters, collected in a configuration file, to assure a high degree of configuration level intended to specify the algorithms to be evaluated in each simulation session and both the boundary and the initial conditions.



The simulator is a python module named "axbdsim.py" that operates on the basis of a working environment provided through a configuration file. The simulator may be executed from the command line by issuing the command:

```
python axbdsim.py configuration_params
```

where `configuration_params` is the path of the configuration file of the simulator.
During the simulation a log file is generated in the same directory where the simulator was run. The log file is named axbdsim<date-time>.log, where <date-time> is set to the actual date and time.

Each line of the configuration file contains a statement that initialises a parameter of the working environment, with the following syntax:

```
PARAMETER_NAME=PARAMETER_VALUE
```

Statements can appear in any order. Lines starting with # are considered comments.
Since the simulator can operate with different algorithms, the configuration file shall provide both the name of the algorithm and the path to the algorithm-specific configuration file.
After the definition of all the required parameters, a simulation session can be executed and the resulting output is stored in a log file.

The set of information reported in each log file is compliant with the adopted evaluation criteria of the algorithms. A summarised output includes statistics, such as:

- percentage of active users
- percentage of the contents filtered on each client
- minimum, maximum, and average number of contents available in the cache of each client
- minimum, maximum, and average number of users' choices.

which are reported in the shape such as follows:

```
STARTED AT 15:36:13 OF 2005/09/30

------------- Simulation Parameters Summary -------------
Start date: 15:36:13 OF 2005/09/30
Simulator Version: 1.1
Algorithms:
Carousel Builder: RANDOM
Filter: Random|1
Cache: FIFO
User model: ML-0.3
Simulation duration: 100 hr.
Simulation step: 1440.0 sec.
Total Simulation steps: 250
Total Objects: 3883
Object Bit Rate: 1 Mb/s
Assumed Object Size: 7200 GB
Carousel Bit Rate: 5Mb/s
Number of clients: 1000
Cache size: 25GB
User Interaction Delay: 1800 sec.
Average User Interaction Period: 3600 sec
------------- Step 0 of 250-------------
Day: 0      Time: 0.0 sec.
New object(s) available from carousel: 1
['Best Men', '1997']
Filter pass rate: 56%
Objects in the cache: 0 (min)    0(av.)     1 (max)
Active users = 43% (AV)
User Choices: 0 (min)    0 (av.)    1 (max)
------------- Step 1 of 250-------------
Day: 0      Time: 1440.0 sec.
New object(s) available from carousel: 1
['Bird of Prey', '1996']
Filter pass rate: 48%
Objects in the cache: 0 (min)    1(av.)     2 (max)
Active users = 21% (AV)
User Choices: 0 (min)    0 (av.)    1 (max)

.
.
.
.

------------- Step 248 of 250-------------
Day: 4      Time: 357120.0 sec.
New object(s) available from carousel: 1
['Mona Lisa', '1986']
Filter pass rate: 52%
Objects in the cache: 27 (min)    27(av.)     27 (max)
Active users = 25% (AV)
User Choices: 0 (min)    63 (av.)    82 (max)
------------- Step 249 of 250-------------
Day: 4      Time: 358560.0 sec.
New object(s) available from carousel: 1
['Double Team', '1997']
```

```
Filter pass rate: 54%
Objects in the cache: 27 (min)    27(av.)     27 (max)
Active users = 25% (AV)
User Choices: 0 (min)    64 (av.)    83 (max)
*************************************************************
*********  FINISHED
*************************************************************
```

5.7.2.4 Technical Details

reference to the AXFW location of the demonstrator	A path in the CVS: https://cvs.axmedis.org/repos/Applications/axbdsim
List of libraries used	Python standard libraries
References to other major components needed	None
Problems not solved	• Availability of different real surveys
Configuration and execution context	path in the CVS https://cvs.axmedis.org/repos/Applications/axbdsim/doc/test Operating systems: Windows and Linux
Programming language	Python

5.8 Algorithms

5.8.1 Carousel builder algorithm

5.8.1.1 PURE_RANDOM_CAROUSEL_ALGORITHM

The carousel is built randomly picking the items from the pool of MediaLens movies. Each item is delivered together with the corresponding resource. A fixed duration and bit-rate are assumed for each item (and resource). Therefore a new item will be available from the carousel depending on the actual carousel bit rate. No check on repeated items is performed.

Parameter name	Description	Type	Unit	Constraints
CONTENT_DURATION	The duration of each item.	integer	sec.	>0
CONTENT_BIT_RATE	The bit-rate of each item (i.e. the bit-rate required to play or stream each item).	real	Mbit/s	>0
CAROUSEL_BIT_RATE	The actual bit-rate of the carousel (referred to the payload).	real	Mbit/s	>0

5.8.1.2 OPTIMIZED_CYCLIC_CAROUSEL_ALGORITHM

A carousel of N items is selected from the MovieLens pool. The selection is optimised using the MovieLens user ratings (a given percentage of the carousel is assigned to each class of user ratings). Items are assumed to be delivered just before the corresponding resources. Every time the whole carousel has been delivered a given percentage of its items are replaced by new items, chosen with the same optimisation rules. A fixed duration and bit-rate are assumed for each item (and resource). No repeated items shall be present in the carousel, however the carousel renewal shall not care about redelivering items that were already present in the past carousels.

Parameter name	Description	Type	Unit	Constraints
CONTENT_DURATION	The duration of each item.	integer	sec.	>0
CONTENT_BIT_RATE	The bit-rate of each item (i.e. the bit-rate required to play or stream each item).	real	Mbit/s	>0
CAROUSEL_BIT_RATE	The actual bit-rate of the carousel (referred to the payload).	real	Mbit/s	>0
CAROUSEL_SIZE	The number of items (and resources) that are carried at each cycle in the carousel.	integer	-	>0

Parameter name	Description	Type	Unit	Constraints
CAROUSEL_USER_RATING_QUOTAS	A list of 5 quotas (i.e. percentages of the carousel size assigned to each class of user ratings).	a list of 5 integers	-	each quota >0 and <100
CAROUSEL_RENEWAL_RATE	The percentage of the number of items that are renewed at each cycle.	integer		>0 and <100

5.8.2 Filtering algorithms

The present section describes the criteria adopted to propose, evaluate and finally choose the cache contents Filtering Algorithms. The basic idea is to define a roadmap that pass through a few phases where for each phase a different filtering algorithm is implemented and the related outcomes collected and stored. The choice of the more suitable algorithm shall arise by comparing the simulation results, taking in account, other than the algorithm precision (convergence degree) itself, its computational costs also. Before starting the algorithm description, it could be useful to spend a few words to introduce some related concept.

The information filtering is strictly connected to the notion of Recommendation System intended as a process having the effect of guiding the final user to interesting objects in a large set of possible options. The present analysis includes the most popular Recommendation techniques such as the Collaborative Filtering, Content Based, Demographic Based and Combined Recommendation Systems that vary for the different kind of their training set. In particular, the Collaborative Filtering Algorithms work uniquely on the basis of the user's ratings commonalities while the Content Based ones act considering the object features. The Demographic Based algorithms, in analogous way, elaborate the corresponding recommendation by considering users personal data similarities. The mentioned Recommendations Systems, if separately taken, has strength and weakness, therefore the last proposed Combined Technique shell be implemented and evaluated to overcome their limits and to empower the global convergence degree.

For each class, a specific algorithm is considered as detailed in table below:

Recommendation Techniques
Collaborative Filtering (Naïve Bayesian)
Content Based (Winnow ?)
Demographic Based (Kruwlich?)
Combined Techniques(CF +CB+DB)

5.8.2.1 RANDOM_FILTER_ALGORITHM

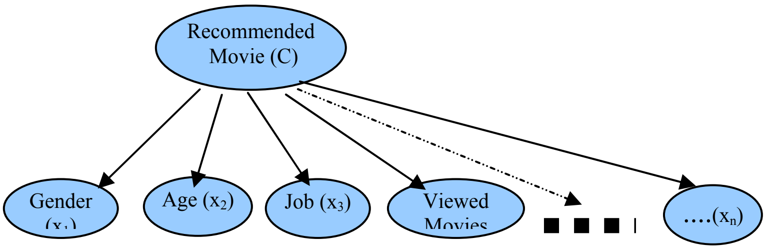
A random decision is taken by the filter, according to a given probability and without considering any content feature or user profile. This algorithm first considered and it is mainly intended to be used as a reference when evaluating more sophisticated filtering algorithms.

Parameter name	Description	Type	Unit	Constraints
RANDOM_FILTER_PASS_RATE	Probability that an item is accepted by the filter and passed to the cache.	real	-	in [0, 1]

5.8.2.2 NAIVE_BAYESIAN_FILTER_ALGORITHM

As previously reported (see the table above), the Naïve Bayesian algorithm belongs to the Collaborative Filtering (CF) recommendation class that make suggestions about objects likely appreciated by the final user. The CF basic approach consists of finding correlations among users (similarities) and consequently arranging recommendations. Therefore, it finds items of potential interest (not seen by the current user but rated by the others) and predicts the rating the current user would give to them on the basis of the similar users liking level. In short, the Naïve-Bayesian suggests a specific object because users similar to the current one appreciate it. When this suggestion is proposed to the user, he could make an action selecting the object itself. If this event occurs, the user profile shall be modified updating the appropriate weights assigned to the object typology.

Formally, as it is well known, a Bayesian Network encode the joint probability distribution over a set of n variables $\{X_1, ...X_n\}$ as an acyclic graph and a set of conditional probability distribution. Naïve models are particular and simplified instance of Bayesian Networks, so named for their “naive” assumption that all the X_i variables, given a variable C, are statistically independent. The naïve Bayesian model uses a two-level tree as inference network with a root and several child nodes (such as the sample network depicted below):



With observed attribute values x_1, ...x_n, the probability for the C classification is given by the mathematical expression:

$$\text{Rec}(C)= \text{argmax}\ c_{j\square C}=P(c_j)\prod_i P(x_i \mid c_j)$$

where

- x_1,...,x_n are possible attributes of this analysis,
- c_j is one of the values of the class C which is to be classified
- $P(c_j)$ is the probability calculated on the c_j frequency in the considered training set
- $P(x_i \mid c_j)$ is the conditional probability to have the x_i attribute value given c_j

The issue to assign weights to the Bayesian inference network corresponds to find the more suitable way to handle the uncertainty conditions taking in account the past experiences. That process is known as statistical learning and it is based on the availability of an appropriate training set which shall include, in this experimental phase, information about the users in terms of personal data and user preferences.
The hereinafter table reports a trivial sample of training data originating from the MovieLens survey

User	***Gender***	***Age***	***Job***	***Viewed Movies***
1	Male	18-24	Doctor	Action
2	Male	45-49	Farmer	Drama
3	Female	25-34	Programmer	Action
4	Male	50-55	Doctor	Comedy
5	Female	45-49	Doctor	Comedy

In short, the learning process simply calculates the probability for each hypothesis, given the data, and makes prediction on that basis. That is, the predictions are made by using all the hypotheses, weighted by their probabilities. In this way learning is reduced to probabilistic inference.

The Naïve Bayesian Algorithm is carried out according to the following pseudo code:

```
for each movie in the carousel
     if the movie cj  is not present in the cache and is not seen by the user11
        calculate on the basis of the learning database
            Rec(movie cj )= P(cj  has been choose by users 12 ) •i P(xi | cj 13)
```

[11] It is to be intended as current user

```
                    score[movie  $c_j$ ]= Rec(movie $c_j$ )
            cached_item= movie $c_j$ where j is  max(score[movie $c_j$ ])
```

Therefore, if a suggested content is afterwards chosen by the current user, additional information14 is stored in the training database contributing to the learning process.

Strength and Weakness

The presented algorithm is usually efficient (see the result section) although conceptually simple, anyway for granting appreciable results should be available a larger number of input attributes together with a wide range of values and a suitable amount of users in the database.

Algorithm Results

Parameter name	Description	Type	Unit	Constraints
NAIVE_BAYESIAN_FILTER_TRAINING_SET	File containing the training database for the Naïve Bayesian filtering model	string	-	not null

5.8.3 Cache

5.8.3.1 FIFO_CACHE_ALGORITHM

The cache is managed as a FIFO (First In First Out). Items (and resources) that was put in the cache the longest time ago are discarded to create space for new incoming items.

Parameter name	Description	Type	Unit	Constraints
CACHE_SIZE	Size of the content cache of each client.	integer	GByte	

5.8.3.2 LRU_CACHE_ALGORITHM

A LRU (Least Recently Used) strategy is adopted. Cached items (and resources) that was accessed by the user the longest time ago are discarded to create space for new incoming items.

Parameter name	Description	Type	Unit	Constraints
CACHE_SIZE	Size of the content cache of each client.	integer	GByte	

5.8.3.3 LFU_CACHE_ALGORITHM

A LFU (Least Frequently Used) strategy is adopted. Cached items (and resources) that was accessed by the user the least number of times are discarded to create space for new incoming items.

Parameter name	Description	Type	Unit	Constraints
CACHE_SIZE	Size of the content cache of each client.	integer	GByte	

[12] The value of c_j can be assumed to be the movie genre such as comedy, action, drama and so on. Therefore if c_j is a comedy movie, P(c_j has been viewed by users) represents the probability a comedy movie appears among the viewed movies in the considered training set. If we consider the table as the referred database (it is obviously reductive) the P(c_j = comedy has been choose by users)=2/5

[13] The value of c_j can be assumed to be the movie genre such as comedy, action, drama and so on. Therefore if c_j is a comedy movie, and x_i an user attribute such as job=doctor, the P(x_i | c_j) represents the conditional probability of a user being a doctor considering he has viewed a comedy movie before. If we consider the table as the referred database (it is obviously reductive) the P(x_i = doctor | c_j = comedy has been viewed by users)=2/5

[14] This information includes User, Gender, Age, Job and Viewed Movies according to the sample training data table.

5.8.4 User behaviour

5.8.4.1 ML1_SU_USER_ALGORITHM

The algorithm assumes a population[15] distribution categorized by the same statistical parameters used in the MediaLens sample survey (age, sex, occupation). A single user per client is also assumed.
When a user is instantiated it is assigned to a demographic class, identified by the triplet age-sex-occupation, according to a probability directly calculated from the statistical distribution. Therefore, the actual statistical distribution of the population will tend to the statistical distribution provide by the initialisation parameters only for large number of users.
TO BE COMPLETED

Parameter name	Description	Type	Unit	Constraints
NUM_CLIENTS	Number of client terminals in the simulation.	integer	-	>0
USERS_SEX_MALE USERS_SEX_FEMALE	Statistical distribution on the gender basis. Each parameter identifies a percentage of the overall population.	real		>=0 total = 100.
USERS_IN_UNDER_18_AGE_RANGE USERS_IN_18_24_AGE_RANGE USERS_IN_25_34_AGE_RANGE USERS_IN_35_44_AGE_RANGE USERS_IN_45_49_AGE_RANGE USERS_IN_50_55_AGE_RANGE USERS_IN_OVER_55_AGE_RANGE	Statistical distribution on the range of ages basis. Each parameter identifies a percentage of the overall population.	real		>=0 total = 100.
USERS_OCCUPATION_OTHER USERS_OCCUPATION_ACADEMIC_OR_EDUCATOR USERS_OCCUPATION_ARTIST USERS_OCCUPATION_CLERICAL_OR_ADMIN USERS_OCCUPATION_COLLEGE_OR_GRADSTUDENT USERS_OCCUPATION_CUSTOMER_SERVICE USERS_OCCUPATION_DOCTOR_OR_HEALTH_CARE USERS_OCCUPATION_EXECUTIVE_OR_MANAGERIAL USERS_OCCUPATION_FARMER USERS_OCCUPATION_HOMEMAKER USERS_OCCUPATION_K-12_STUDENT USERS_OCCUPATION_LAWYER USERS_OCCUPATION_PROGRAMMER USERS_OCCUPATION_RETIRED USERS_OCCUPATION_SALES_OR_MARKETING USERS_OCCUPATION_SCIENTIST USERS_OCCUPATION_SELF-EMPLOYED USERS_OCCUPATION_TECHNICIAN_OR_ENGINEER USERS_OCCUPATION_TRADESMAN_OR_CRAFTSMAN USERS_OCCUPATION_UNEMPLOYED USERS_OCCUPATION_WRITER	Statistical distribution on the basis of professional classes. Each parameter identifies a percentage of the overall population.	real		>=0 total = 100.
USER_INTERACTION_DELAY	Time at which users start interacting with the content.	integer	seconds	>0 total = 100.
USER_INTERACTION_PROBABILITY	Express the probability for the user to be in active status	real	-	>0
USER_INTERACTION_FREQUENCY	Time interval between two consecutive user interactions	integer	seconds	>0

5.9 Results

This section was intended to report the results of the evaluation phase of the simulation; but the activity has been closed before completition of such evaluation, due to the CRS4 withdrawal from the AXMEDIS project.

[15] The population parameters can change on the basis of the USERS_MODEL value: the example reported in the table is compliant with the user behaviour model indicated by the survey results of MovieLens.

6 I-TV Client Optimisation and onsite Content Integration (CLOSED)

6.1 Introduction

The “Cache-based distribution on iTV” application model represents an efficient solution for delivering multimedia content to a large number of users, that are in such a way able to access a personalised list of AXMEDIS objects using a “local on-demand” access paradigm. However, this application model can be further improved by performing an onsite content integration among AXMEDIS objects from the cache, in order to provide on-the-fly personalised channels that can be locally delivered to the viewer, either with a local-pull or a local-push (Axmedis channels) paradigm.

Application model:		***Access model:***
broadcast distribution	→	*push*
cache-based distribution (onsite filtering and caching)	→	*local pull*
cache-based personalised distribution (onsite content integration)	→	*local pull/push*

6.2 Objective

The objective of the present work is to identify and validate a client-side aggregation tool for the “Cache-based Personalised Content Distribution” application model, described in section 18.9 of DE2.1.1a (User Requirements and use cases), that extends and improves the adaptation engine of the “Cache-based distribution on iTV” application model, described in section 4. Designing such a system involves considering several aspects and issues. In particular:

- content composition standards shall be evaluated in terms of the capability to generate onsite multimedia applications (AXMEDIS channels) by aggregating objects that are available in cache; the possibility to provide AXMEDIS channels templates in the form of scripts that are distributed by content providers and are subsequently instantiated on the client platform shall be evaluated as well;
- a further analysis of content description standards shall be carried out in order to identify the metadata that can semantically describe the structure of audio-visual content and therefore provide access to specific segments of audio-visual content;
- an analysis of the possible business models enabled by client-side content composition shall be carried out, with specific focus on PVRs;
- the state of the art of automated content composition techniques shall be evaluated, with particular attention to client-side solutions operating from cached content.

6.3 Preliminary analysis

6.3.1 Analysis of content composition standards

Several content composition standards exist, and should be evaluated in terms of their suitability to the purposes of the present application model. **SMIL** (Synchronised Multimedia Integration Language, W3C) is a powerful XML-based scripting language for the production of synchronised multimedia content. SMIL provides a full control of timing and display layout. **TVML** (TV program Making Language, ….) is a scripting language for producing TV programs by combining computer graphic animations, synthesised speech, virtual camera movements and available audio-visual content. **MHEG-5** (ISO/IEC 13522-5) is an object oriented descriptive language for producing simple multimedia applications composed by interactive widgets, text, audio-visual streams, etc. Requiring little computing resources on the client, it is particularly suitable to consumer applications in streaming distribution environments, such as interactive TV. A step ahead over MHEG-5 is **MHP** (Multimedia Home Platform, ETSI TS 101 812), a powerful Java-based language specifically targeted to interactive TV platforms. **Macromedia Flash**, a proprietary multimedia suite based on an open file format (swf), is mainly targeted to producing vector-based animated web content. **BML** (Broadcast Markup Language), an XML-based standard for interactive TV applications adopted by ARIB (the Japanese association of broadcasters) addresses the same needs of MHEG-5 and MHP. Although based on xHTML and CSS, BML is primarily targeted to streaming environments. **MPEG-4** (ISO/IEC 15938) provides a standardised representation of interactive multimedia content in terms of media objects, either natural or synthetic, hierarchically organised within a scene. Although the object-oriented organisation may be suitable to perform some kind of client-side personalization, MPEG-4 has been specifically conceived to address the specific needs of authors and content providers, rather than the personalization needs of end users. A detailed analysis of SMIL vs. MPEG-4 BIFS[16], carried out by Cheock-Eleftheriadis 2002, highlights the fact that SMIL is rather a higher level textual format for creating dynamic presentations by integrating and synchronising multimedia data, and so it is relatively easy to author. On the other hand, MPEG-4 BIFS is aimed at describing the spatio-temporal organisation of multimedia objects in a 3D scene and covers also many other aspects such as client-server interactivity, stream multiplexing, file format, etc.

The following table provides a quick comparison of the above mentioned standards from the point of view of their suitability to the "Cache-based Personalised Content Distribution" application model.

technology / standard	developed / proposed / published by	primary application domain	Notes	Suitability
SMIL	W3C	web	Specifically focused on creating multimedia presentations by combining external audio-visual content. Very good layout, timing and transitions support.	●●●
TVML	NHK (Japan Broadcasting Corporation)	TV, broadcasting	Rather a 3D rendering engine targeted to the production of synthetic audio-visual content based on a script. However it can manage external audio-visual content. Free player available, but not open source. Should be considered if the availability of virtual characters (actors, anchormen, etc.) is a requirement. Out of scope.	●
MHEG-5	ISO	TV, broadcasting	Very targeted to the interactive TV domain, with a lot of support for widgets. Limited support for audio-visual content (only streaming, no transitions, etc).	-
MHP	ETSI	TV, broadcasting	As above, provides many features and stronger computing support (Java), in spite of a higher complexity.	-
MPEG-4 BIFS	ISO	TV, broadcasting	Covers many aspects of the production ad distribution chain in a broadcasting environment. It is quite complex to address the purpose of a simple client-side scripting language.	●●
Flash	Macromedia	web	Strong support from the content development community. Open file format, but manly relies on proprietary tools.	●
BML	ARIB (Association of Radio Industries and Businesses)	TV, broadcasting	Similar considerations as MHEG-5 and MHP.	●

Possible technologies for automated TV program generation

Notes:

Suitability level : ●●● *very suitable,* ●● *suitable,* ● *possibly suitable, - unsuitable*

SMIL represents the best trade-off between content composition features and simplicity of the authoring process.

According to DE3.1.2B (AXMEDIS Framework and Tools Specifications) an internal SMIL player will be integrated in the AXMEDIS framework in order to control the presentation behaviour of multimedia content. AXMEDIS clients will be able to interpret and execute SMIL-compliant scripts carried by AXMEDIS objects, delegating the rendering of audio-visual content to specific modules.

6.3.2 Analysis of business models of content composition

As pointed out in Dempski 2002, two different business models are possible for content composition. The first one is a *subscription-based business model* which exploits the increased value of personalised contents, due to the optimisation of the viewing experience (in terms of time and quality of content); while the general broadcast could be available for free, the personalization service should cost a small fee.

[16] MPEG-4 BIFS (Binary Format for Scenes), defined in ISO/IEC 14496-1 (Mpeg-4 Systems)

The other business model is the typical rating from *advertising*, although it would be greatly improved by data about viewers; in fact, information about audience (both demographic and related to their viewing preferences), could be used to organise personalised advertisements. In this case, personalised advertisements could be inserted in the virtual channels and treated in the same way described for the other kinds of content, by means of metadata.

Although the most effective way to personalise commercials is based on metadata, an interesting kind of advertisement personalization have been proposed in Dempski 2002: interactive advertisements allow the viewer to select, for example, the colour of a car; the information about the favourite colour of the car could be recorded in the PVR in order to present all the forthcoming advertising about cars with the same car colour. This kind of content personalization is possible just using graphics effects locally. In this way users' privacy would be ensured because this kind of content adaptation would be performed on client side, without being transmitted to the server.

In Dempski 2002 is presented also MyNews, an interesting news channel personalization, where the selection of the segment of content which would be interesting for the viewer is achieved by comparing content metadata related to single segments with the user profile (metadata about user preferences and usage history). The same model is suitable also for any kind of programs which can be segmented in an acceptable way (sports, music, reality shows, etc.).

To realise this kind of application, two are the possible scenario on the client: recording all the content and then operate with the selection, or recording only the selected contents. A menu for random accessing is an important tool in order to have an easier way to watch the virtual channel. Obviously MyNews is suitable also for the insertion of personalised advertisements.

6.3.3 PVR business models in AXMEDIS satellite broadcast distribution

Although similarities between AXMEDIS "Cache-based distribution on iTV" application model and PVRs appear quite evident, there is one key difference between the two environments. The PVR model stem from digital TV, i.e. from a broadcast distribution of streaming content. AXMEDIS distribution, instead, is not based on streaming, but involves transferring objects to the clients, either with a point-to-point or broadcast delivery. Although, as long as enough bandwidth is available, a real-time access paradigm could still be possible, there are no requirements in AXMEDIS to support the "live streaming" that is typical of set-top boxes.

In the following table, a list of requirements at the basis of PVR business models is analysed and compared with the two AXMEDIS application models based on a broadcast distribution. The aim is not to define new requirements, but to understand whether some PVR business models can be applicable to potential business models based on the AXMEDIS framework.

TV-ANYTIME PHASE-1 KEY BUSINESS MODELS[17]	**AXMEDIS application models**	
	"Cache-based distribution on iTV" application model	"Cache-based personalised content distribution" application model
A PDR can capture and play back content.	yes	-
The PDR can offer live pause.	Streaming is not supported by the application model.	-
A PDR has an on-screen menu of content already captured.	yes	-
The PDR system provides a schedule so a viewer can choose content to record from it.	yes	-
A PDR can enable new content to be captured and replaced or be added alongside old content on the	yes	-

[17] this column is an excerpt from TV-Anytime Specifications on Phase-1 Benchmark Features (document SP001V1.1), Table 5.7 "Key Phase 1 Business Models"

	AXMEDIS application models	
PDR.		
The PDR allows users to select for capture, single or multiple episodes of a series or other program groupings.	-	yes
The PDR allows the management of items 'cued' for capture.	yes	-
The PDR enables retro-record (capture entire program or ad starting up to x minutes into the live stream) or gives option to capture at later date when it is available.	Streaming is not supported by the application model.	-
The PDR system supports storage partitioning and management of multiple users and/or service providers.	yes	-
The storage space on a PDR system can be managed by consumers or providers eg: items to be deleted next, permanently stored etc:	yes	-
The PDR system can automatically capture content based on viewer behavior (profiling)	yes	-
Viewer profiles can be aggregated and analyzed from individual or groups of PDR's for targeting services	yes	-
The PDR enables the insertion of pre-captured advertisements or promotions into live/broadcast content based on viewer profiling.	Streaming is not supported by the application model.	Streaming is not supported by the application model.
The PDR allows the insertion of pre-captured advertisements or promotions into stored content being played back, based on viewer profiling.	-	yes
There can be remote control of the PDR system functionality (eg: capture settings, profile settings, etc.).	no, but possible	no, but possible
The PDR system allows the selection of segments of programs for recording based on information provided by the service or content provider.	-	yes
Some content is provided with index points and a playlist enabling 'passive' highlight or other playback modes.	yes	yes
The PDR system allows the navigation and exploration of content segments using provider indexes (eg: step through, short/long form etc.).	yes	yes
The PDR system can create single, personalized programs from individual 'personally linked' segments.	-	yes
There is support for multiple users (separate recorded content menus, profiling, parental control etc.).	yes	yes
There are flexible usage rules (limited viewing windows for example) on the PDR system.	yes	yes
Consumers (on a bi-directional PDR system) can store their 'personal' content on Network storage devices.	no	no
Consumers can move their personal profiles to different PDR's or PDR systems in other physical locations.	no	no
3rd parties or service/content providers can provide recommendations, content referencing and resolution of content potentially from many other providers.	yes	yes
Providers can force download 'premium/PPV' content to the PDR system (i.e. LocalVOD).	yes	yes

6.4 Methodology

The adopted methodology is based the following actions:

1. refine the objective;
2. define the scope, i.e. circumscribe the application domain, considering a few significant application scenarios;
3. identify the constraints;
4. identify the architectures of the possible solutions;
5. review the proposed solutions in terms of architecture complexity, standards compliance, interoperability, etc.;
6. validate the proposed solutions using a prototype.

6.4.1 Objective refinement

The objective of the research activity is to identify a client-side content composition tool capable to provide personalised content by dynamically composing Axmedis objects that are available in the cache. The composition shall be done according to the user profile and shall meet explicit requirements imposed by the user.

6.4.2 Scope

The application model based on client-side content composition will be circumscribed to the following application scenarios:

1. personalised news channel, based on the cyclic repetition of a news program continuously updated and dynamically generated by composing news services selected from a pool of Axmedis objects available in the cache;
2. personalised music program, based on the dynamic composition, in a time sequence, of music items already in the cache;
3. personalised advertisement, based on the dynamic insertion of one (or more than one) targeted ads at specific insertion points within a video program (ex. in a film), according to the user profile;

Moreover, it shall be possible to depict further usage scenarios defined by combining the personalised advertisement with the news channel or the music program.

Although each of the above listed application scenarios requires some considerations on its own, some general rules shall be identified in order to build a common composition mechanism applicable to any scenario.

6.4.3 Constraints

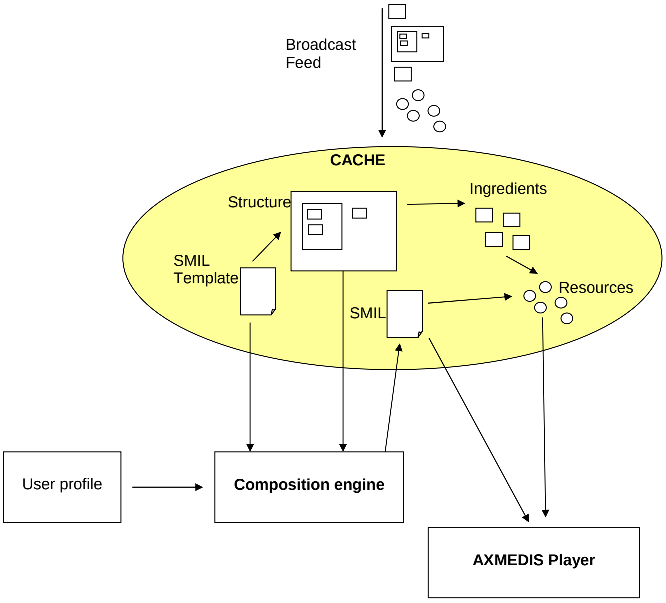
The following constraints have been identified:

1. the “Cache-based personalised distribution” application model based on client-side content composition shall be compatible and totally integrated with the “Cache-based distribution on iTV” application model based on content filtering and caching, analysed in chapter 4.

6.4.4 A possible approach

The proposed solution is based on the following assumptions:

1. the following AXMEDIS objects are made available by the content provider and distributed periodically through the satellite broadcast data channel:
   - an AXMEDIS composed object describing the structure of the target composed content;
   - an AXMEDIS object that includes a resource containing a SMIL template that defines the spatio-temporal layout of the target composed content;
   - a pool of AXMEDIS objects to be used as the ingredients of the target composed content;
2. the content composition may only operate on objects available in the cache;



6.5 Metadata for content composition

Describe the impact on metadata → further set of Mpeg-7 MDS high level descriptors to describe the structure of the target composed content.

6.6 Content composition algorithms

Describe the intended algorithms for selecting the items (ingredients) that will be part of the target composed content.

6.7 Composition engine

Describe the design of the composition engine (XSLT based).

7 Conclusion

The present document reports on the activity of research for an optimised integration of the distribution of content in the AXMEDIS project to PC and STB through satellite data broadcast, and to STB via streaming.

Section 3 already reported on the characteristic aspects of a distribution in multicast: advantages, existing protocols and tools, possible optimisations. The EUTELSAT Secure Data Broadcast platform has been chosen for the distribution via Satellite for the AXMEDIS platform.

New section 4 reports on the two Set-Top Boxes compliant with the AXMEDIS model, receiving content from satellite data broadcast and via streaming. These devices are used for implementing the demonstrators of WP9.3 and WP12.2.

Previous sections 5 and 6 reported on the mechanisms that provide a “Cache-based distribution” models, based on client-side caching and filtering, and on onsite content composition.

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10 Glossary

PVR	Personal Video Recorder
STB	Set-Top Box

BSG	Broadcast Service Guide
EPG	Electronic Program Guide
EMP	Eutelsat Multimedia Platform
ACK	Acknowledgement
NACK	Negative Acknowledgment
RTT	Round Trip Timing
OPENSKY	Broadband Service provided by EUTELSAT
SDB	Satellite Data Broadcast
DVB-CBMS	Digital Video Broadcast – Convergence of Broadcast and Mobile Services