



Automating Production of Cross Media Content for Multi-channel Distribution

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DE12.1.5.3

AXMEDIS-4HOME Final report and Success Story

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Abstract This document is a report of the AX4HOME approach within the AXMEDIS Consortium.

Keyword List: DTV, OMA, Domains, Tool Servers, Rights Ontology

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1 Executive Summary and Report Scope (BBC)

The 4HOME project was able to conclude successfully with the launch of the 4HOME back office and OMA gateway and completion of the development and testing of the Recorder Application based on the AXMEDIS concept, implemented on a home PC. In addition the 4HOME consortium were able to supply a DRM protection Tool Server, an integrated Ontology verification Tool and assist the AXMEDIS technical partners in their implementation of the AXMEDIS Domain concept. This report gives an overview and summary of each of these aspects.

The major sections below cover the details of contribution and success by each of the partners in their respective roles within the 4HOME Consortium. These are BBC (coordinator and 4HOME recorder application), Telecom Italia (4HOME Back Office and OMA Gateway), ETRI (Provision of the DRM Protection Tool Server), PKU (Analysis and part of PMS Domain Service and Database) and sDae, (the Rights Ontology and associated Authoring Tool).

The first section of this report gives a more general project progress summary from the coordinator.

2 Project Summary (BBC)

2.1.1 Project coordination

During the project lifetime the BBC has coordinated the majority of the deliverables on behalf of the 4HOME partners. These partners have taken on different roles within the consortium and focused on specific areas of interest, often liaising with different technical partners from the larger consortium.

The coordination activity was focused on the set up of the consortium and initial interfacing. Once the project could meet together, more dialogue was possible and the details of requirements in terms of the AXMEDIS framework could be resolved between the 4HOME partners and the AXMEDIS technology partners. The preparation of DE12.1.2 [1] and DE12.1.3 [2] were in some respects the formal resolution of the project plan in the light of the information newly available from this closer dialogue.

2.1.2 Project launch

The launch of the AX4HOME project was itself a challenge with such a large architecture described across so many documents. Many of these documents are written in the context of system labels that did not readily and easily describe the functionality of each sub system. Much effort had to be made in understanding the overall system partitions and the functions being performed by each. For instance, what might be generally described as “security management” that might contain say “Rights Brokers”, or “licence servers”, mapped to the AXMEDIS ‘Protection Management System’ within the suite of documents and more commonly appears as just “PMS”.

The documents are based around an object orientated view of the system and deal with software interfaces at a low level making it difficult for the reader to quickly absorb what is available from a user perspective. In addition many of these documents although including functional modules, do not fully describe implementation details and do not reveal the inner workings from which limitations to the architecture may stem. . There were a number of updates published during the 4HOME project which were important for understanding and for enabling communication and formulating appropriate questions when interacting with the technical partners. However, whilst these later releases did help to understand more fully the architectural view of the AXMEDIS framework, the limitations on the implementation at any point were only discernable through installing and testing.

2.1.3 First Deliverables.

The first deliverables consolidated the final approach to be taken by the 4HOME partners. This was an important milestone because only at this point did a clearer mutual understanding emerge between the 4HOME partners about what was proposed and what was technically possible in terms of the AXMEDIS framework. To some extent this fragmented the working group as they each concentrated on their respective parts and specialties in the light of the dialogue. However, this exercise was successful and the result was captured in the first deliverables 12.1.4.2 [1] and 12.1.4.3 [2].

2.1.4 Project Evolution.

Once the initial deliverables were closed, the roles of the partners with respect to the requirements and dependencies on the tools of the other partners was clear, though the exact technical nature of the AXMEDIS tools was to be worked through as the demonstration components were assembled. Much of the project dialogue from here on in was between the individual partners and the central project teams responsible for the AXMEDIS tools themselves

2.1.5 Project Convergence

During the project evolution, the development and assembly of the demonstrators by the 4HOME partners was dependent on the correct and robust operation of the tools. This in turn depended upon reporting to the AXMEDIS technical partners, technical issues arising and regular updating and reconfiguration of the prototypes as new tool updates were released. Such an organic process naturally converges once the requirements are held firm, but may never fully complete as more deeper analysis and better system performance only becomes possible when all tools are operating in an adequate manner.

As a result, the technical work scheduled for WP12.4 and WP12.1.5 effectively continued until the last possible moment that would allow organized user testing for the completion of WP12.1.6. For the case of the Integrated Access to Premium Content [Section 6] this was on July 11 2008 , and for the Recorder Application [Section 5] 23 July 2008. All partners remained with the project beyond their initial commitment up until the final date of the larger project lifetime.

2.1.6 Review of the risks of the 4HOME project

From the outset, the major identified risks were challenging. Joining a major project of such complexity is onerous since there are many aspects to consider and an immense amount of detail and activities to understand. As with all activities of this kind the jargon and terminology, though roughly common, may not be exactly aligned with other activities. Dealing with such a comprehensive and evolving body can be all-consuming and stifle contribution from the participants.

The second risk was the estimation of the work required to achieve the identified tasks, once clarified in terms of the existing AXMEDIS framework. This depended on the accuracy of estimating the maturity of some AXMEDIS components or external technologies required to further develop the tools.

The evolution of the project described below grappled with these issues. In addition the different cultures of the 4HOME partners, the level of involvement required and the ‘ownership’ of technologies requiring interfacing with the AXMEDIS framework added to the complexity and in some cases limited the nature of participation.

These problems were to some degree countered through the diligence of the technical support and working relationships of the representatives of the partners. Inevitably though, some aspects of the workplan progressed more slowly than anticipated as much more effort was required by all partners concerned (not just 4HOME partners) to analyze and address technological issues as they arose. With the lions share of understanding of the limitations and system architecture of the AXMEDIS framework resting with the AXMEDIS partners, it was they who controlled the pace of development as some reported implementation issues were more challenging than others, especially where a large number of AXMEDIS Tools were used

together. Communication also consumed time and effort, especially if it was likely that other documentation should be consulted before pressing a point.

In the event, the development teams were able to continue to collaborate beyond the initial agreed time limit for participation and this was instrumental in bringing the activity to a satisfactory end.

3 DRM Protection Tool Server (ETRI)

The ETRI team based in Seoul, Korea was successful in developing a DRM Protection Tool Server to supplement the AXMEDIS concepts. Using their in-house expertise, ETRI volunteered to assist the consortium in providing an external Tool Server that could be integrated with the AXMEDIS tools to allow a client to attain any plug-in lacking from their initial installment.

Such a tool server is essential to support business models that depend on proprietary plug-ins for such things as encryption algorithms or other processing functions particular to a specific process. These plug-ins can be delivered in binary format to preserve the proprietary nature of the protection processing tool. The plug-in interface itself is the AXMEDIS plug-in interface.

The main issue that ETRI resolved during discussions at the architecture specification stage was the means by which the communication between tool server and the AXMEDIS client could be integrated into the AXMEDIS client.

Given that ETRI have no jurisdiction over the AXMEDIS Tools, advice was taken on the nature of the interface and this was specified in DE12.1.3. ETRI then provided both a Tool Server and Tool Server Client to enable testing of their server. This server can deliver the DRM Protection Tools in a format compatible with the AXMEDIS plug-in interface.

Although the Tool Server client was built to allow tight integration with the AXMEDIS tools, the protocol between the Tool Server and Tool Server client is not using an open standard and therefore will not become part of the AXMEDIS Framework. Final integration into the AXMEDIS client itself is outside the scope of the AX4HOME consortium.

The setup and manual for the ETRI tool server is given in deliverables AXMEDIS-DE12-1-5-1-AXMEDIS-4HOME-AXMEDIS-Demonstrator-Setup. It requires the database interface support of MySql which is available and can be easily installed.

The following is a screenshot of the server side.

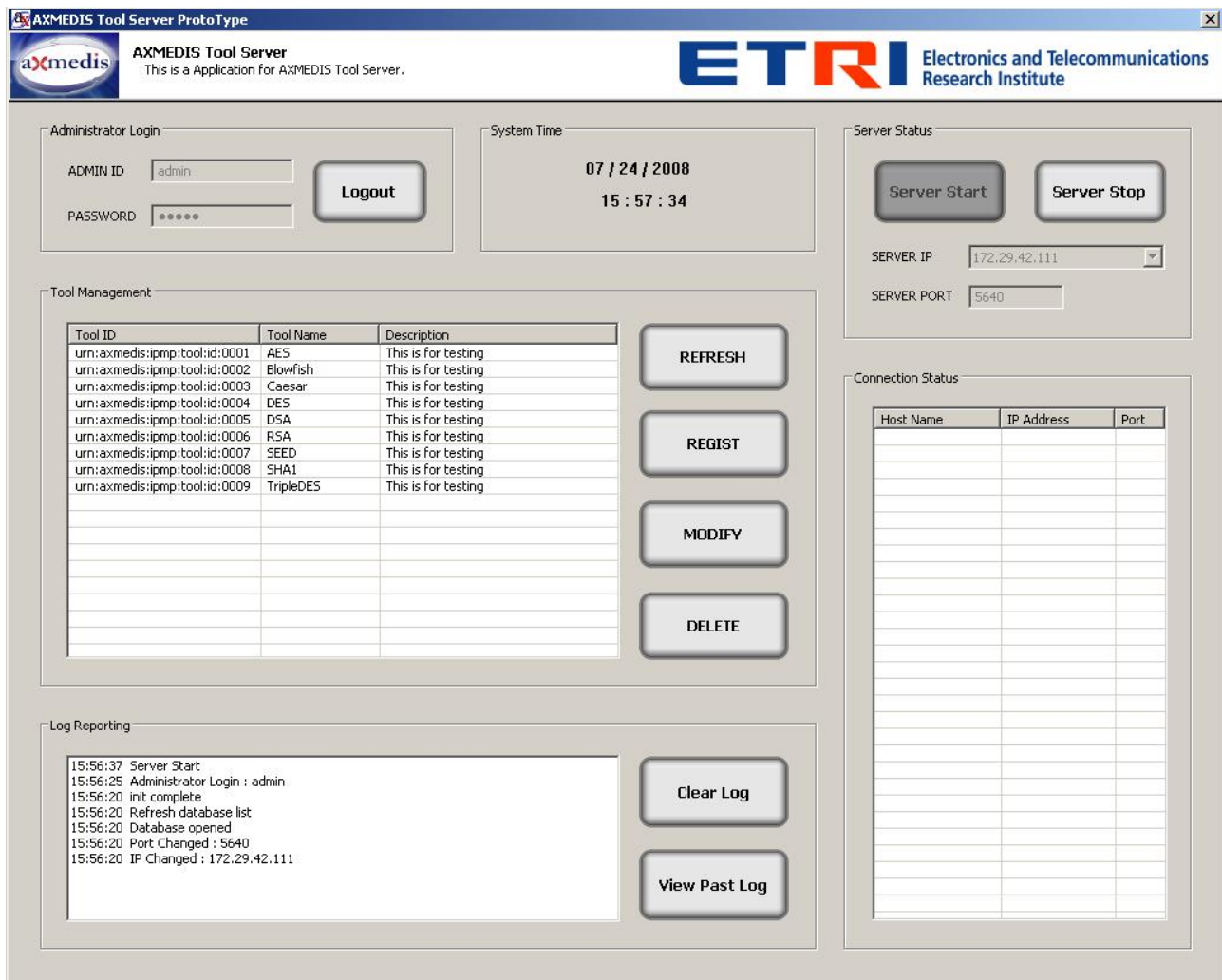


Figure 1 ETRI Tool Server Interface for AXMEDIS

The Tool server interface shows the connection status, a log of server activity and a list of registered tools available. It is very easy and convenient for users to control such as register, modify and delete tools. The followings show the basic functionalities of the Tool Server provided.

- Registering – to register new tool including its' parameter setting
- Modifying – to modify existing tool's parameter
- Deleting – to delete useless tool

In addition, this Tool Server provides a downloading function if requested by the Test Client.

The Test Client has developed for testing of tool downloading function, and as a result ETRI provides the downloading APIs that are described in the 5.3.3 section of the DE12-1-4-1 document. It supplied to the consortium by ETRI that demonstrates use of the Tool Server is also provided with a user interface.

The following is a screenshot of the client side.

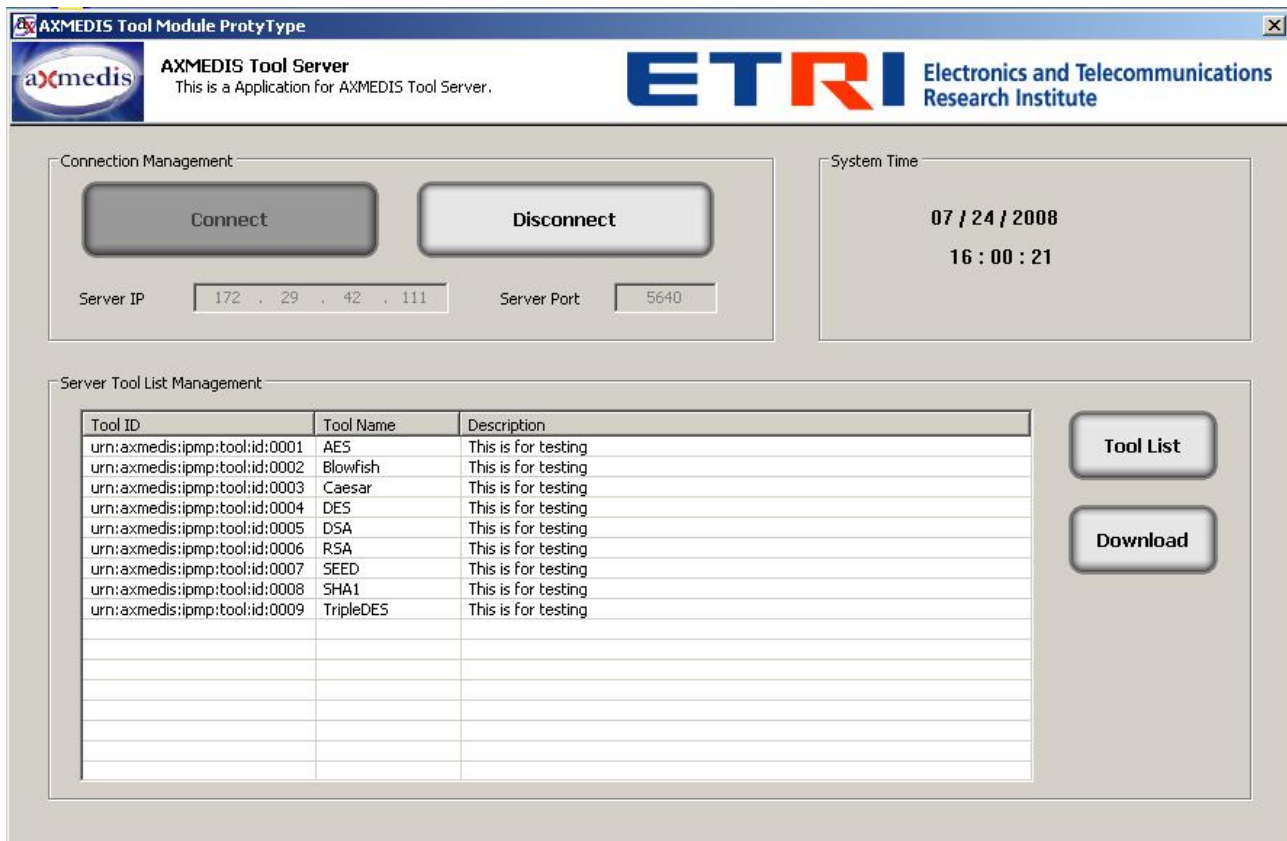


Figure 2: User Interface for Tool Server Test Client.

The Test Client interface allows easy startup and connection, plus a list of available tools for download. If users choose any tool in the tool list for downloading, the Test Client downloads the tool from the Tool Server with a XML messages.

The followings show the basic functionality of the Test Client provided.

- Downloading – to download requested tool

4 Domain Management (PKU)

Although the AXMEDIS Framework was designed with a concept of a Domain Home and Domain Factory, details were not documented at the initiation of the 4HOME Project. Furthermore, the evolving business models using rights protected content in the home are typically based on a number of devices registered by the home user. This architecture potentially supports a wider range of business models by limiting the total spread of content user under the auspices of a single user.

Analysis of the AXMEDIS Domain Home architecture was undertaken by PKU and modules proposed to extend the working model to allow the building of user domains including devices. In addition to the user management in domain environments, PKU suggested the concept of device management in a domain, which supplements the architecture of Domain Home module in AXMEDIS. PKU not only proposed the concept of device management in the domain, but also PKU designed the relevant APIs to the device management for UPC to implement it. Also, PKU gave the description of some use cases in which the concept of domain is applied and tested. By introducing the device management, users are able to form a device-networked domain in a home/incorporation environment, which means that a user can play his/her content on any of his/her devices when he/she includes the device into the domain. Integration of the

management of users and devices in the domain enables further business models for digital media consumption.

For completion of the implementation of the AXMEDIS Domain Home and integration into the PMS architecture, UPC the AXMEDIS partners responsible for the Domain and Protection Management Services (PMS) functions implemented and initiated a Domain Home service. This enabled users to create domains using the client Domain User Device Manager shown below. For the application used in the AX4HOME demonstrator, this allowed a user created domain to include all the user home devices such that content bound to the home user devices (after creation by the AX4HOME Recorder) could be associated with the User Home Domain Certificate. In this way the use of the Home domain was integrated as part of the AX4HOME recorder application.

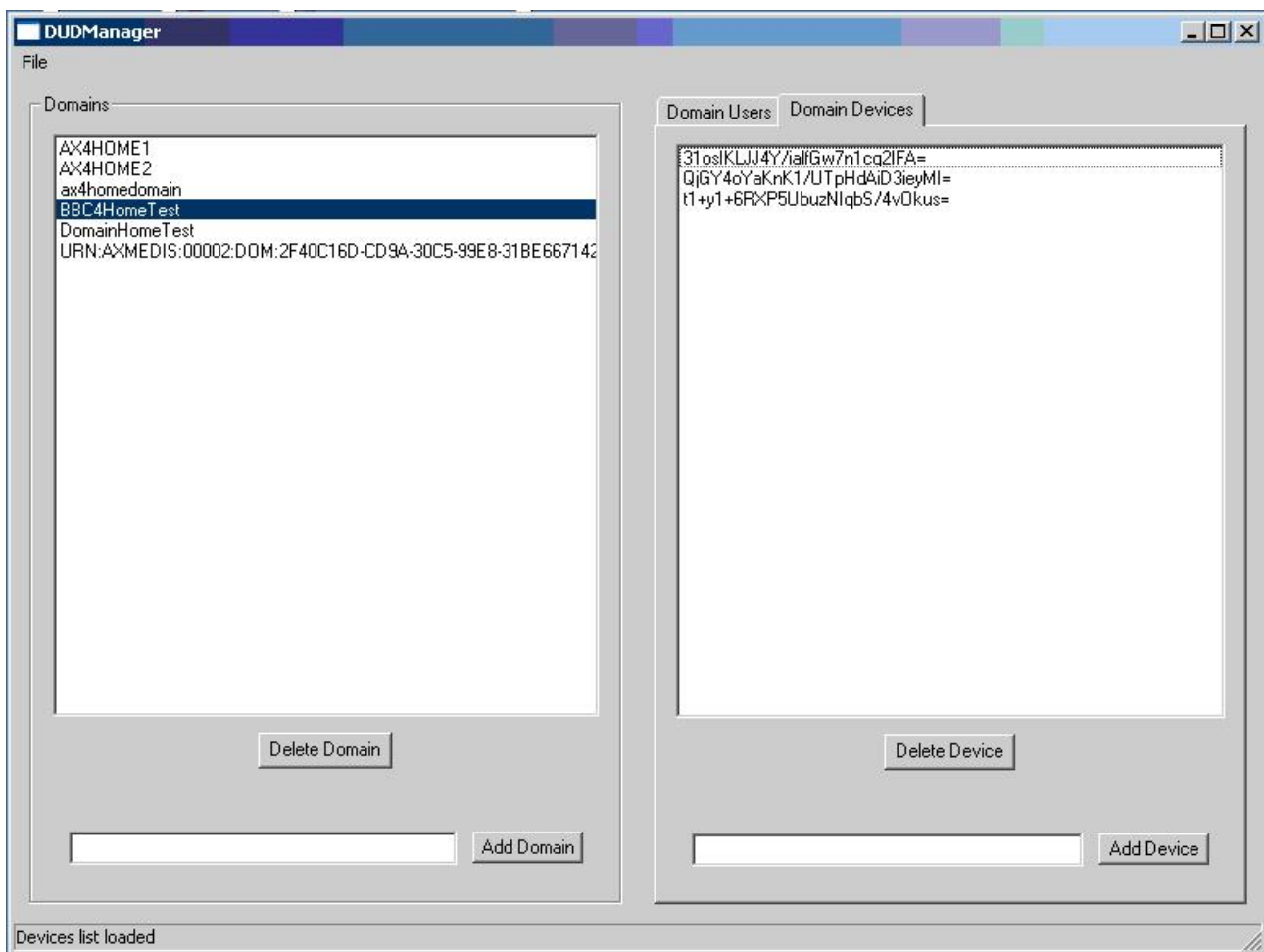


Figure 3:Domain User Device Manager Showing Active Domains

In addition to the working Domain Manager hosted by UPC for purposes of demonstration and testing, there is also a version that can be installed on a User Home Network.

5 The AX4HOME Home User Recorder Application - incorporating AXMEDIS support (BBC)

5.1 BBC Technical Work

The nature of the experimental work by the BBC has been in three areas.

The first was to develop a domestic PC based recorder application that capture live off-air DVB broadcasts as requested by the user. The success of this depended upon the openness of an API on a domestic platform that can be used in this way. Although the MS Windows Direct show API was selected, there were inevitable issues using this constantly developing environment.

The second was to support the application with AXMEDIS tools in order to facilitate the creation of an AXMEDIS object on the client. This part rested heavily on the completeness of the AXMEDIS tools. Though the functionality was designed and understood by the technical partners, much of the assumed technicality was not universally understood, not implemented or not tested. This phase of project involved testing many assertions, reporting findings, awaiting explanations, bug diagnosis or later tool releases. There were also some features that were addressed specifically to allow the implementation of the BBC application.

The third and final aspect is the testing of the 4HOME recorder concept itself. This phase involves demonstrating the finished prototype to end users to see whether the application utilising such functionality is an attractive proposition, and whether the bringing together of the rich AXMEDIS functionality into a consumer facing application adds potential value to the industry.

A high level overview of the concept is shown below. The Home user has access to the enhanced AXMEDIS Object based upon the broadcast content over DVB-T and the supporting AXMEDIS Tools which assemble the presentation using AXMEDIS Content from AXEPTOOL P2P network and supporting http services.

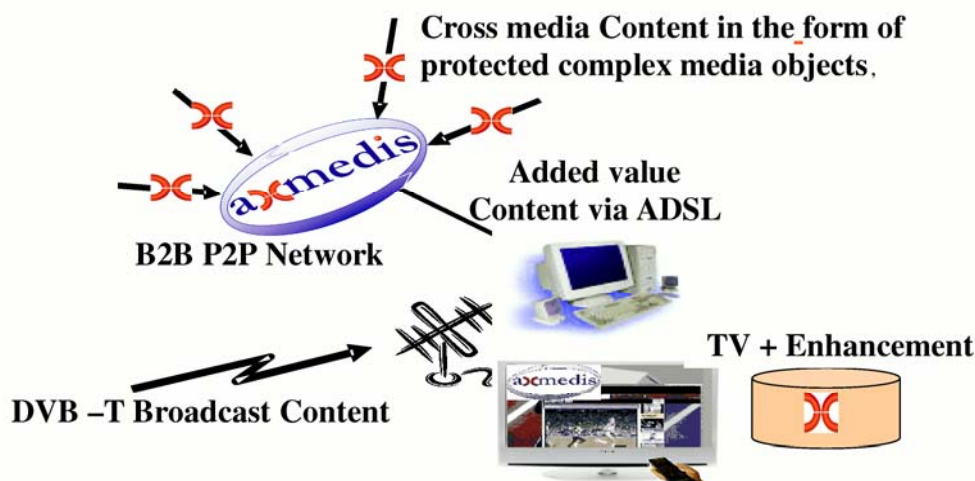


Figure 4: High Level Schematic of Recorder Concept

5.1.1 Development of the Recorder Application.

The development of the Recorder Application took place over the duration of WP12.4 and WP 12.1.5. This is a significant application as it has to work over the Microsoft Windows Platform. Technically the challenge

was to use the C++ language over the MS DirectShow interface to interact with a commercial ‘off the shelf’ DVB-T compliant receiver card. The success of this was documented in the deliverables DE12.1.4 (AXMEDIS-DE12-1-4-1-AXMEDIS-4HOME-AXMEDIS-Component-Integration-Prototypes-and-Documentation) and DE12.1.5 (AXMEDIS-DE12-1-5-1-AXMEDIS-4HOME-AXMEDIS-Demonstrator-Setup).

Once the basic Recorder Application and supporting EPG was completed, further modifications took place as more users, BBC staff and personnel gave feedback. During the evolution of the project, the following ‘softer’ issues were addressed by the appropriate technical partners within the AXMEDIS consortium.

- The total screen area required to display all functionality made the operation on a PC cumbersome. Modifications were made to enable the recording status, the recording schedule and the preview window separable.
- The amount of user feedback when selecting a recording needed improvements
- The introduction of a flexible way to suggest ‘enhancements’ was improved
- The playback presentation was improved in line with internet player symbolism and the choice of playing trailers given to the user.
- The startup process was automated, triggered from the selection of a programme on the EPG

A screenshot of the later version of the recorder interface is shown below.

The initial EPG selection is done from a web based live EPG service. This can be viewed through the AXEPTOOL interface which ensures the AXEPTOOL is running. This is important as a user selection on the EPG will start up the recorder application (if not already started) which in turn silently communicates with the AXEPTOOL to determine the status of any enhancements required from the P2P network.

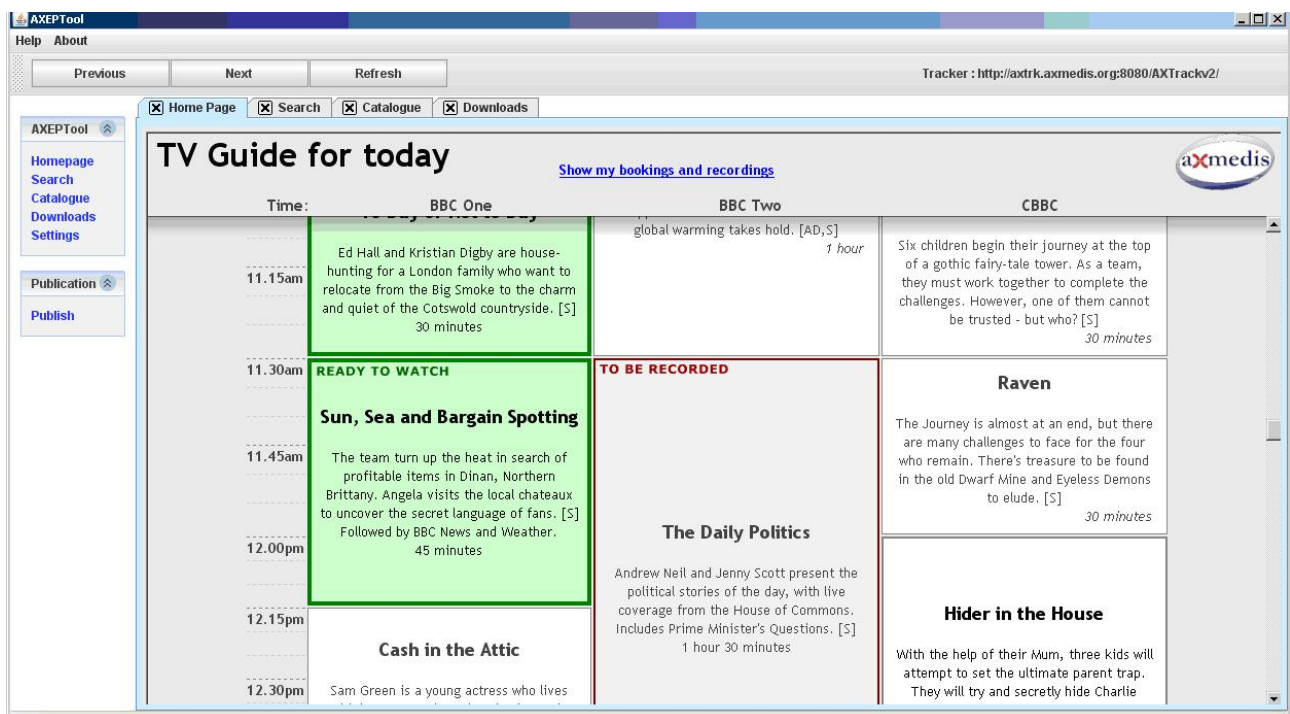


Figure 5 User EPG with some User Status Feedback

Once started, the recorder status window appears in the form below.

My Bookings and Recordings				
Programme	When	Duration	Status	
● Jakers!	03:05 pm on Wed 16 July	20 mins	Recording	
● The Daily Politics	11:30 am on Wed 16 July	1 hour 30 ...	Booked for recording	
✓ Sun, Sea and Bargain Spotting	11:30 am on Wed 16 July	45 mins	Ready to watch!	
✓ To Buy or Not to Buy	11:00 am on Wed 16 July	30 mins	Ready to watch!	
✓ Homes Under the Hammer	10:00 am on Mon 14 July	1 hour 1 sec	Ready to watch!	
✓ The Daily Politics	12:00 pm on Mon 14 July	30 mins	Ready to watch!	
✓ Raven	11:30 am on Mon 14 July	30 mins	Ready to watch!	
✓ Time Warp Trio	03:30 pm on Fri 11 July	20 mins	Ready to watch!	
✓ Sorry, I've Got No Head	04:35 pm on Fri 11 July	25 mins	Ready to watch!	

Jakers!

CBBC. The Cat Came Back....and Back!
 Porcine adventures with Piggley Winks
 and friends. Sweet shop owner Miss
 Nanny offers a reward for the return of
 her lost cat. [S]

This programme currently being

Figure 6: Recorder Status Window

User selection of a completed (recorded and stored) programme from the list results in the opening of the AXMEDIS player and the typical playback presentation is shown. In this example the user can select the main video, the associated trailer, a link to an external website or stimulate the subsequent recording of an event related to the promotional trailer.

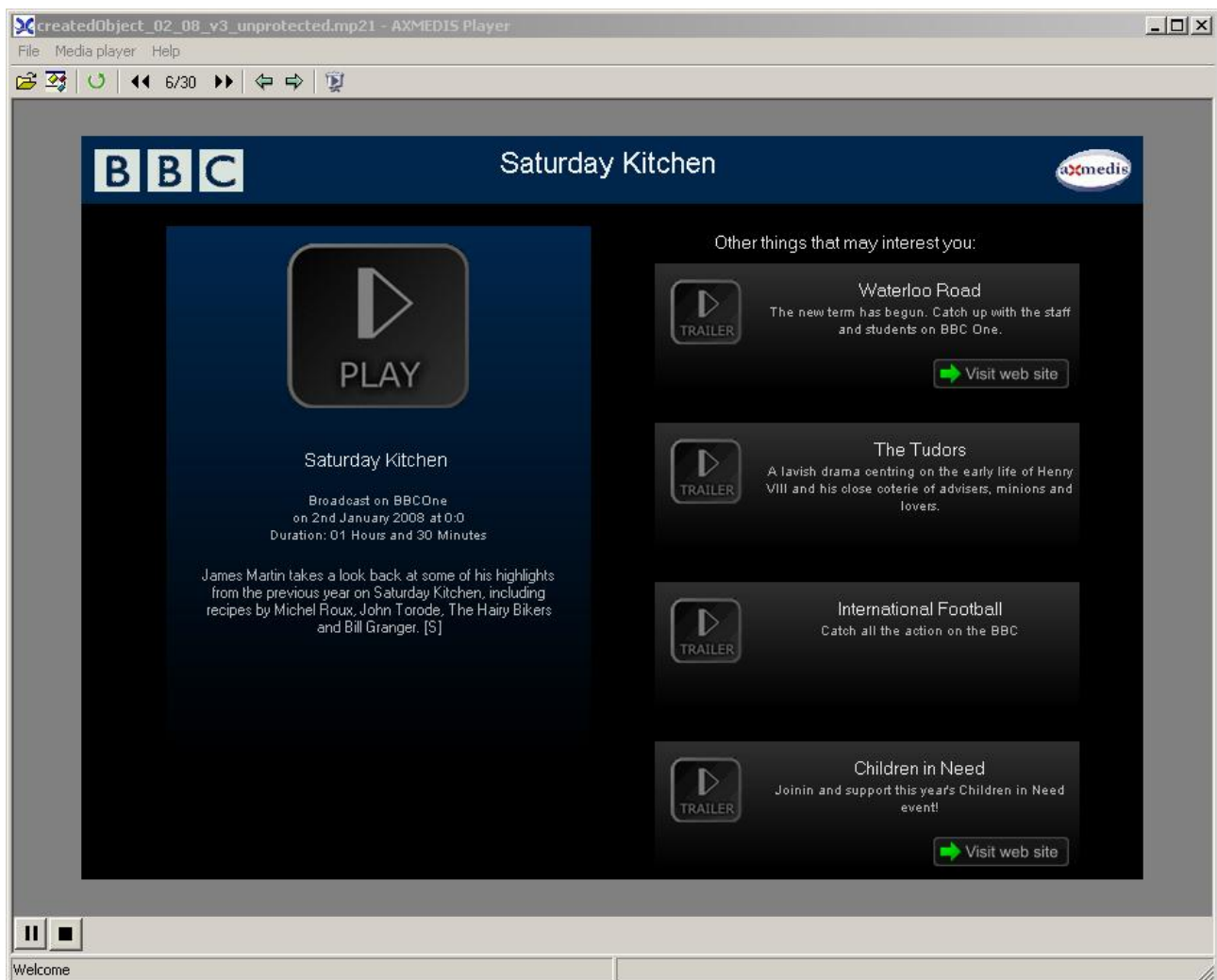


Figure 7: The User Playback Interface

The playback of the video fills the AXMEDIS Player screen.

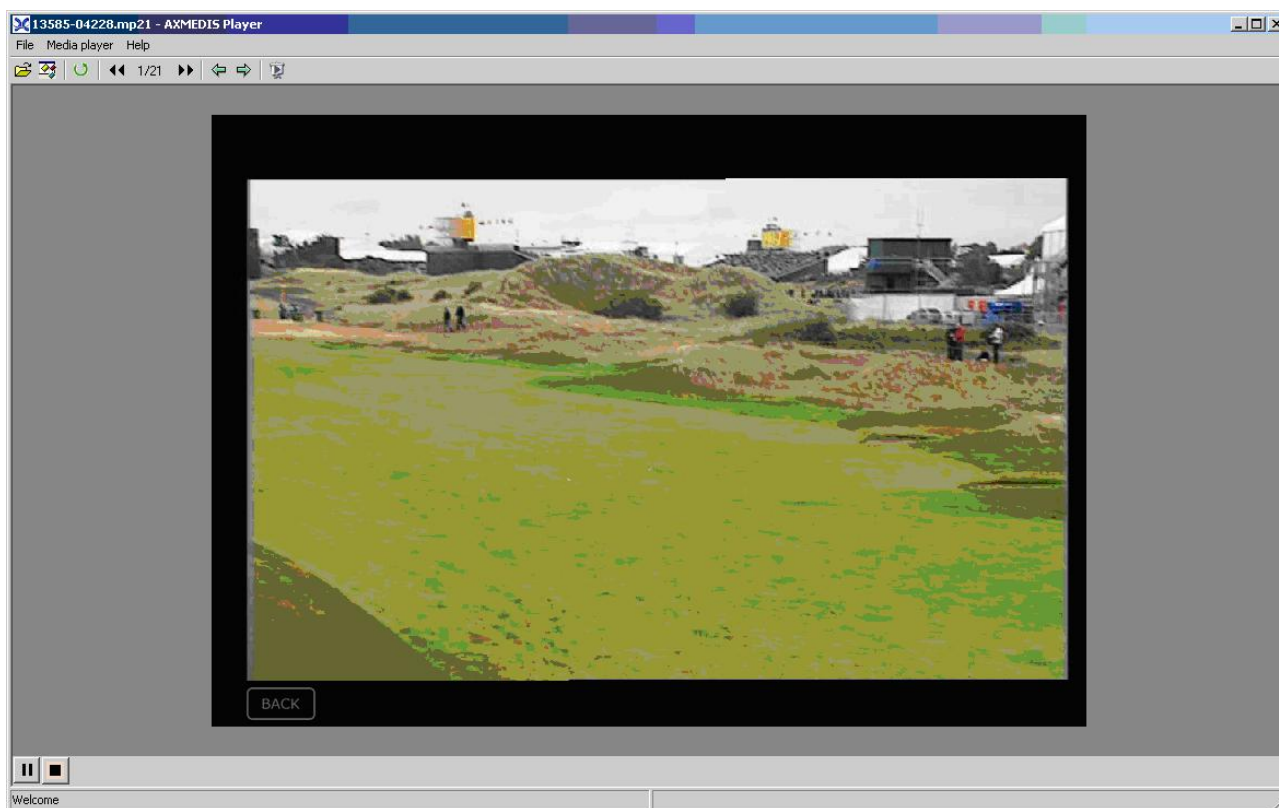


Figure 8: Playback of Audio/Video feature

5.1.2 Integration of the AXMEDIS Tools

The integration of the prototype components and the AXMEDIS Tools of WP12.1.4 was an iterative process as the AXMEDIS Tools themselves were evolving from working prototypes. Initially, using the release of the AXMEDIS tools available at the time, progress could be made which reinforced the principles of the AXMEDIS framework. Limitations of these tools however prevented a simple build of the proposed system. These limitations were in areas such as:

- The SMIL editor capabilities did not exercise all the features necessary to assemble the sort of presentation envisaged.
- The initial Javascript manual did not cover the API required to build the system (though some of these were implemented.)
- Editor and players had limitations handling moderately large video files
- Encryption tools added hugely to the time of opening the video files
- There were issues using the Protection System, change of PMS and affects of adding an HDD drive
- There were complexities in testing the Protection System that resulted in 'blocking' when the tools were re-installed or updated. These were not initially understood and hampered development.

- The playback of Audio and Video was not synchronized in the player.
- The Rule Editor and RuleExecutor functionality and operation needed updating as bugs were discovered and then resolved, or new improved features introduced.
- Testing updates required all tools to be stable and isolating single problems was time consuming.

Progress in the development of the project was entwined with the analysis, testing, reporting, resolving and re-releasing the AXMEDIS tools. Often releases were very modular and included only specific components, making tracking of the build status on the demonstration clients difficult and adding to the reporting and verification difficulties. However, through close working with the AXMEDIS technical partners, the system was very substantially improved over the life of the project, bringing performance of the player and editor into line with the performance of comparable commercial offerings. This was essential before any User Testing of the completed application could take place.

These issues were dealt with through email reporting as they were raised and preceded throughout the WP12.1.4 and WP12.1.5 work items and into the final stages the AXMEDIS project. Time spent at verification meetings was also used to liaise with the AXMEDIS partners and demonstrate the problems on the prototype to assist in their understanding of where the critical problems were. These meetings were also used to receive and test the latest improvements available even before release - and so give feedback and update the outstanding issues affecting progress. In this way the 4HOME project acted as a test bed for the Tool releases throughout its lifetime and was effectively stressing certain aspects of the AXMEDIS framework and implementation. The final critical aspects of the demonstrator were resolved by 23 July 2008, enabling an end to end demonstration robust enough for user testing to be carried out.

The completed AX4HOME recorder is an implementation of the system outlined in DE12.1.3 [2]

5.2 Testing the 4HOME Recorder Application

User testing of the AX4Home recorder application was undertaken over 2 days. The tests and the results are fully reported in [5]

The final conclusion from 5 is copied here for completeness.

“The recorder application was well liked and was considered a ‘next step’ by many of the respondents undertaking the test, with some thinking it was ‘obvious’ to others who were fascinated by the web support (even though this is already in place), it seemed to help direct people to the correct pages and through the enhancements give a more continuous experience between TV programmes, associated trailers and web support. It also made sense in that it benefitted from the PC style user interaction for recording and also the potential of large scale video playback not associated with internet on-demand streaming or download. One tester also appreciated the comparative richness of the broadcast schedules compared with an internet catch up service.

It was considered a prototype, not a completed proposition as the player occasionally froze and there were obvious limitations to the design that were highlighted in this report, though some these are more to do with time invested rather than fundamental technology limitations, except perhaps limitations of the SMIL engine that limited some of the desired functionality such as full screen and programme transport”

5.3 System Limitations

The 4HOME Recorder Application contains the functionality envisaged in the specification document DE12.1.3.1. It uses the AXMEDIS P2P Tool AXEPTOOL to access the P2P network and locate the broadcast enhancements according to the Recorder Application recommendation list. This 'recommendation list' is served over HTTP and the AXMEDIS objects are retrieved and manipulated using the underlying AXMEDIS Rule Executor

By the time of testing, many earlier limitations of the Recorder Application had been resolved or improved to a level that was able to present a convincing application to the testers. These critical aspects that had been resolved by the AXMEDIS technical partners included:

- Aspects of the end to end security – the way the system handled secure files between accessing an object and creating another
- Aspects of using the protection system to perform un-protection and re-protection in one session were resolved.
- Playback of the presentation through the SMIL rendering engine was made smooth and the A/V synchronized.
- Loading and playback of large encrypted files was enabled very quickly – commensurate with other commercial media players
- Aspects of the Protection System were improved and became reliable
- The stability of the remote servers hosting the essential web servers ('Tomcat') was improved and resolved

In addition to the supporting AXMEDIS Tools, the recorder application itself went through a number of improvements to make the concept more accessible to non-technical users before testing could be performed¹. Work was done to improve the playback presentation that enabled the User to select either the main feature or the trail and we were made aware of a number of user feedback issues when stimulating an action which would leave the user uncertain of the path to take. Improvements were made to the recorder status and EPG selection to overcome these observed shortcomings.

The remaining limitations of the system were considered to have only a low impact on the assessment of the Recorder Application in the user testing environment. These included:

- Lack of Home network. The 4HOME Domain concept would work more effectively from a user perspective with the integration of a home network.
- Testing Cycle. Continuous testing and adjustment of the tools throughout the life of the project may mean we have not exhausted all bugs as new understanding and deeper testing required stability with respect to the bugs discovered. The rate of testing and reporting is itself a limiting factor in the development cycle.
- Robustness of setup

¹ I would like to thank my BBC Colleagues Maxine Glancy and Andy ODwyer for there assistance in shaping the look and feel of the application from their perspective of professional and experienced product assessment.
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- The prototype tested is interfacing with the P2P AXEPTOOL which is cumbersome and resource intensive for an end user device. More suitable would be the AXMEDIA P2P tool which would have done the job but for the lack of interface. A real product would require an enhancement of this application.
- The application is built upon the Microsoft Directshow middleware. This is currently shipped with some versions of the Microsoft Windows Operating System, but required specialist knowledge to install on machines that were not already capable.
- There are a number of AXMEDIS Tools used during operation of the Recorder Application. A professional installer package would be required, customized for this application if the application were to be distributed as a product.
- End to end security. The Ax4home recorder application uses the authoring tools to receive and recreate a new presentation. Consequently the rights assigned to the home user to enable manipulation might also allow abuse of the incoming protected objects under other home-grown scripts. This could be prevented with only a slight extension to the AXMEDIS framework to allow objects to be associated exclusively with protected and authorized scripts thereby excluding unauthorized scripts that may provide alternative actions under the granted user permissions. The current development of including scripts in AXMEDIS objects goes some way in this direction but time was not sufficient to fully explore these opportunities or limitations.

5.4 Further opportunities

Due to the difficulties in establishing a robust demonstrator system until the final project stages, there were new areas of innovation from the AXMEDIS technical partners that were unable to be fully exploited further. In particular, use of the Behavioural Editor – the inclusion of active scripting within an AXMEDIS object would offer the possibility of a further degree of control and may have added to the elegance of the system. Unfortunately this innovation did not become fully functional until May/June, beyond the envisaged work period of the project.

Further exposure of the application might also be beneficial as the need to explore alternative business models grows. In particular the novel approach of using the broadcast network and the P2P network together has an appeal that can be exploited further.

In our trials, we do not have the benefit of a well understood enhancement service, - it is by its nature an exploratory idea. However, this approach does look appealing, especially if more suitable content could be found (or commissioned) in a real service to the public. This may be based on promoting the broadcast service, providing ‘goodies’ to users of technologies that can access the service or simply be an exclusive supplementary service. The goal of this service would not so much be to reach new audiences, but to promote the use of rights-managed technology that ‘keeps honest people honest’. This platform also has the potential for personalized services and a response to this question is covered in the accompanying report of the demonstration results. [5] (AXMEDIS-DE12-1-5-2-AXMEDIS-4HOME_Demonstration_Report_Documentation). This report also covers the usability issues found with the Recorder Application.

The major challenge with such a service would be the development and deployment of a new platform. Although there is a novel and attractive feature of the AXMEDIS-4HOME platform, the development of a platform for deployment goes much further and covers areas not explored by this project. In particular, the security of the ‘platform’, the dependency on the host client system, implementation auditing, compliance

and conformance to a measurable and observable security standard are all out of scope of the work undertaken here which concentrates only on the overall functionality.

The parameters that can be varied within such a model are also intriguing and would require a real service to work through. For instance, the P2P enhancements could be optimized for quick download and small network utilization, or more heavyweight high value offers, adding to the total content available. They could be few in number corresponding to large audience sectors, or many to give a more niche approach. They could be issued frequently, say more than once per day, or remain more static and can be targeted at programmes or entire services.

There is also scope for more design in the presentation of the objects. One approach considered is the branding of the whole presentation around a programme, with the enhancements being closely tied to the programme. At the moment the design and production of such presentations is experimental, but a number of such working objects were produced. These 'branded presentations' are shown below, and show one possibility for further promoting a programme strand within a user experience. All components are assembled through SMIL and so in principle could themselves be conveyed to the user in an AXMEDIS object as an enhancement for assembly on the client with the usual scripts.



Figure 9: An AX4home playback themed around a BBC Programme 'Top Gear'

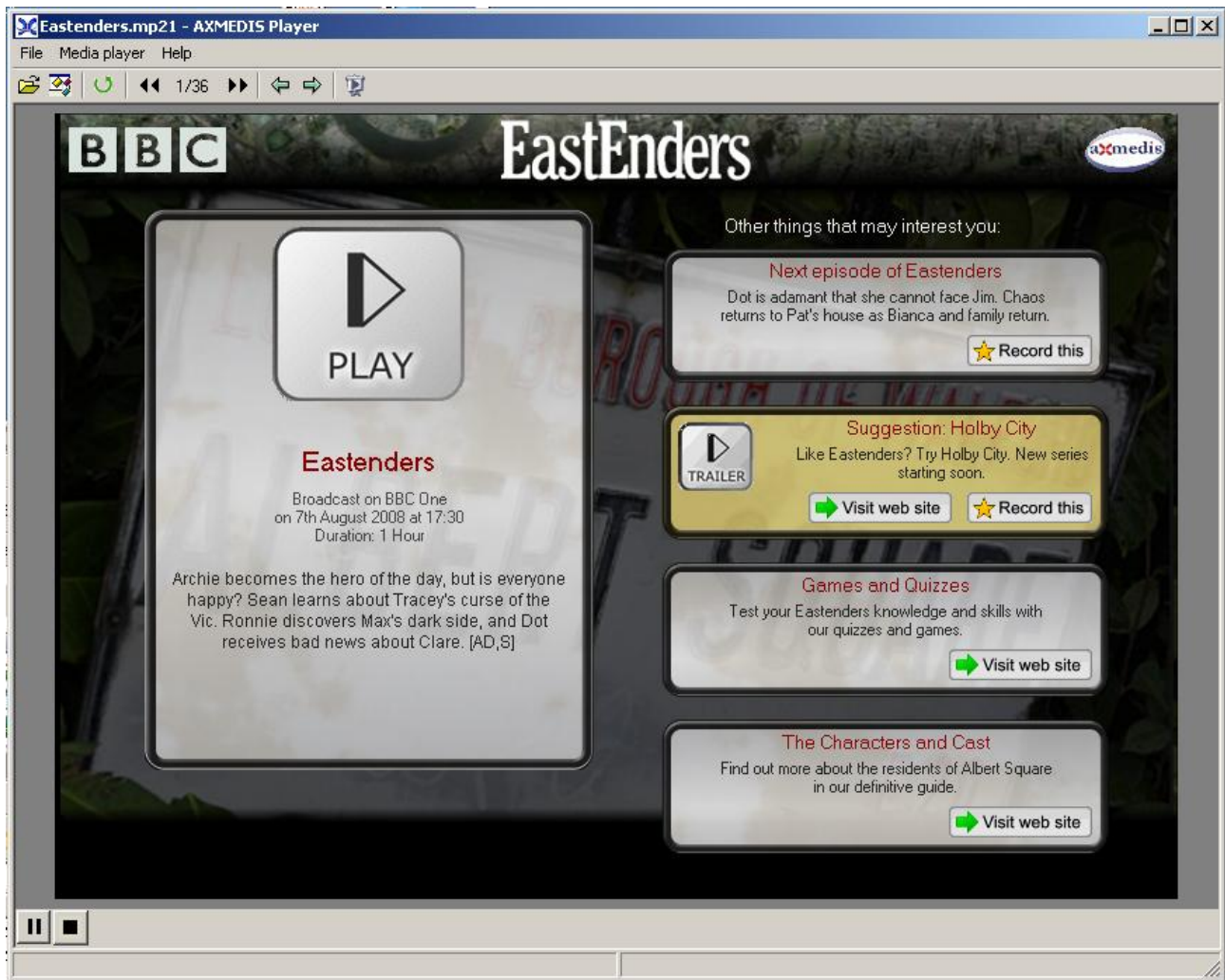


Figure 10: An Ax4Home Playback presentation themed on the BBC Programme 'Eastenders'



Figure 11: An Ax4Home Presentation Themed around the BBC Programme 'Masterchef'

This extra branding requires more production skill than was generally available to the project, but was very helpful in enabling users to absorb the general concepts.

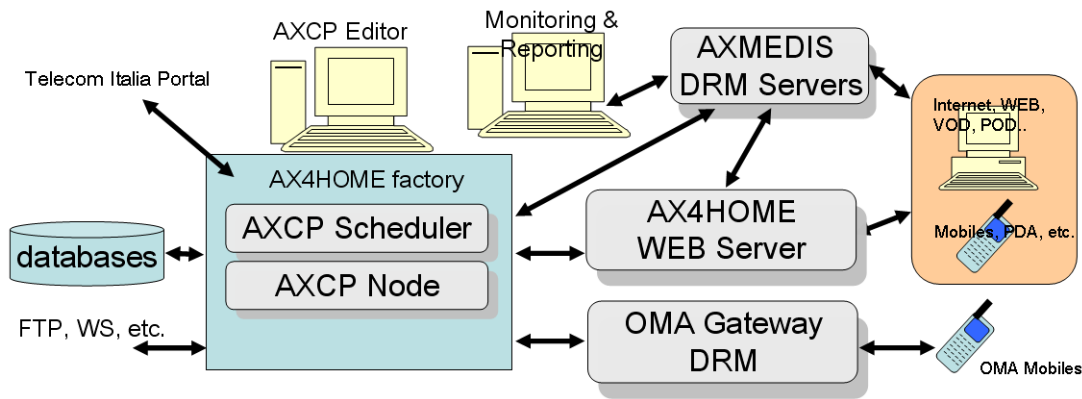
6 Integrated access to Premium content (TI)

6.1 TI technical work

The activity carried out by TI in the project was driven by the intention stated in Deliverable [1] "AXMEDIS-DE12-1-2-1-4HOME-UseCase-and-Req-s-Analysis" to setup an environment where the end user can buy and use Premium content irrespective of the specific delivery channel. The specific delivery channels that have been selected to carry out this experiment are the mobile network and the Internet. This choice was driven by the need to experiment the AXMEDIS technology in a realistic scenario, in order to learn on the difficulties of AXMEDIS setup and customizations that this would imply, while keeping the effort to a reasonable low level, compatible with the low resources allocated to TI in the project. To achieve this goal it was decided to reuse as much as possible technologies already available either from AXMEDIS or from TI, without developing anything new, but simply integrating and deploying such technologies into a prototype which would be used as a test bed for the technical evaluation of the solution. This led to the choice to integrate the OMA DRM v2.0 server available in TI with the AXMEDIS backoffice and client tools provided by the project.

6.1.1 Prototype description

The prototype shows how a service provider can distribute Premium content over fixed and mobile networks in an integrated way. The end user can buy certain Premium content on the service provider portal and then download and play the content (in different formats) on his mobile phone, his PC or both. The goal is to show that the same content (with different quality) may be used on the two clients seamlessly, enabling a business model where the customer can buy the content once, and use it independently of the delivery network (and client device/DRM technology).



In this context the AXMEDIS platform has been used as a unified solution for the distribution of Premium Content over multiple channels: the Internet and the mobile network. On the client side, it has been assumed that end users would use a PC connected to the Internet when they are at home, and a mobile phone when outside. The PC uses the AXMEDIS technology while the mobile phone is equipped with the standard OMA/3GPP technology.

The backoffice supporting the scenario described above is composed by a specific installation of the AXMEDIS Content Factory based on the AXCP tools, complemented by an OMA DRM v2.0 Rights Issuer (“OMA Gateway DRM”), running side-by-side on a server which has been named AX4HOME Factory. The AX4HOME Content Factory (which is available on line at <http://ax4home.axmedis.org/>) is intended to be a generic repository of any kind of AXMEDIS Objects, e.g. from simple audio tracks, to complex multimedia compositions. However, in order to provide a convenient access to all end users, the distribution of the various Objects is filtered on the basis of their content. As an example, a music shop which only distributes music has been implemented. Moreover, in order to provide a friendly and convenient end user experience we have selected a business model based on subscription which allows open access to all content contained in the music shop library, although content is protected by DRM, in such a way that usage permissions expire and must be renewed every month (e.g. by paying a subscription fee – which is not required in the demo of course). The showcase is described on a web page hosted by the AX4HOME server at http://ax4home.axmedis.org/home/?page_id=22, together with specific instructions for business users, technical users, and end users.

6.1.2 PC client configuration (for end users)

The PC client used for Internet access to AXMEDIS Premium content is configured as follows:

- equipped with the AXMEDIS Player
- using the AX4HOME broadband portal (<http://ax4home.axmedis.org/broadband/>) as the source of Premium content
- using AXMEDIS specific Content Format (based on MPEG-21)
- using MPEG-21 licenses
- using the PMS as DRM server
- certified by AXMEDIS certificates provided by AXCS

6.1.3 PC client configuration (for business users)

The PC client used to upload AXMEDIS Premium content on the AX4HOME Content Factory is configured as follows:

- equipped with the AXMEDIS Editor – to package new content in MPEG-21 format
- using the AX4HOME Content Factory (<http://ax4home.axmedis.org/>) as content repository (requires custom configuration of the Editor)
- certified by AXMEDIS certificates provided by AXCS

6.1.4 Mobile device client configuration (for technical users)

The mobile phone is configured as follows:

- Mobile phone equipped with a native multimedia player and OMA DRM v2 Agent
- Content format: OMA DCF v2 (based on ISO Base Media File Format)
- OMA DRM REL v2 licenses
- using the OMA DRM Rights Issuer provided by TI as DRM server
- certified by OMA and CMLA compliant certificates provided by TI

6.1.5 Backoffice configuration

The following basic services have been installed on the AX4HOME Content Factory since they are a prerequisite required by the AXMEDIS architecture:

- Java SE JDK 5.0.12
- Apache 2.2.4
- MySQL 5.0.41
- PHP 5.2.2
- Tomcat 5.5.20
- Filezilla FTP server 0.9.23

The following AXMEDIS components have been setup on the AX4HOME backoffice (in temporal order):

- the AXEPTool – to connect in peer-to-peer the AXMEDIS-4HOME Content Factory to all other AXMEDIS Factories
- the AXMEDIS data base – to store content and metadata information
- The AXMEDIS Web Services – to provide services to external clients:
 - AXDB support WS
 - AXDB administrative interface
 - Loader-Saver
 - Lock-Unlock WS
 - Crawler WS
 - P2P WS
 - External query support WS
 - PAR query support WS
 - AXDB query support WS
 - Main query support WS
 - User selection archive WS
 - Query web user interface
- the AXMEDIS Content Processing (AXCP) tools:
 - the AXCP scheduler – to schedule rule execution
 - the AXCP grid node – to execute rules
 - (optionally) the AXCP Rule Editor – to modify and test rules

Moreover, the AX4HOME backoffice also integrates TI proprietary technology, i.e. an OMA DRM v2.0 rights issuer, and a simple Open Source PHP portal that has been modified to implement the music shop Web interface (both broadband and mobile version). The OMA DRM 2.0 Server (which is pre-existing know-how

of TI), has been configured to operate as an OMA Gateway in order to be able to receive content from the AXMEDIS platform.

Other AXMEDIS services and tools are used in AX4HOME, which are not part of the AXMEDIS Factory. These are:

- The Protection Manager Support
- The AXMEDIS Certifier and Supervisor (AXCS)
- The AXMEDIS Portal
- The AXMEDIS Player (PC version)
- The AXMEDIS Editor

6.1.6 Integration of AXMEDIS and OMA in AX4HOME

The integration, setup and testing activities, which were supposed to be carried out in successive work packages (WP12.1.4, WP12.1.5 and WP12.1.6 respectively), turned out to be more likely an iterative process, with cycles of repeated installation and testing of the same tools, than a sequential activity, due to the fact that development of tools within the project continued up to the project end. Although this is normal during the development of a new technology, it made the integration and setup of AX4HOME more difficult than expected, also due to the fact that the prototype was depending on external services like the PMS, the AXCS, the AXEPTool Tracker, which were from time to time upgraded to new versions breaking compatibility with older tools. Therefore the activity has been carried out as multiple cycles of installation and testing of the same tools, while the same tools were growing in functionality and performing better in stability at each cycle thanks to the previous cycle of developments performed by the AXMEDIS team.

Examining in detail the setup of each tool, we can say the following:

1. The installation and management of the basic tools required by AXMEDIS but out of scope of the project (Java SE JDK 5.0.12, Apache 2.2.4, MySQL 5.0.41, PHP 5.2.2, Tomcat 5.5.20, Filezilla FTP server) was quite straightforward, but required a bit of system administration skills in order to setup a server in a fairly secure way; the strange thing is that, although these are mostly Open Source tools, which are normally present “by default” on Linux servers, they had to be installed on a Windows machine due to some dependency of other AXMEDIS packages from some Windows service/API.
2. The AXEPTool – the tool to connect in peer-to-peer the AX4HOME Content Factory – has a very simple and straightforward installer but requires the manual configuration of IP port forwarding in case the host is located behind a firewall or a NAT router; moreover, since it is based on Bittorrent, and in most cases the Bittorrent ports are closed by corporate firewalls, it requires a special configuration which is difficult to obtain in a business environment. Lastly, this tool has been updated very frequently during the project requiring its reinstallation several times. It should also be noted that, due to the fact that it uses the local IP ports extensively, this tool cannot be installed on the same machine where the AXCP Scheduler is running (which also uses local IP ports to communicate with the AXCP Grid Nodes), because it locks the ports exclusively to itself.
3. The AXMEDIS data base – based on MySQL 4, we have installed it on MySQL 5 with little effort. It has been updated once during the AX4HOME take up life, unfortunately in a way that broke backward compatibility – so upgrading was necessary.
4. The AXMEDIS Web Services – by far the most complex AXMEDIS technology to setup; it requires a basic knowledge of the Tomcat Application Server, the manual installation and configuration of each Web Service, the manual setup of some external packages and DLLs, the modification of the Java VM Security policy, and a case by case testing of each Web Service. Since there are a total of 12 web services that must be installed in order to setup a content factory, the probability of something going wrong is quite high; actually the first time we tried to setup the Web Services none of them worked properly and it was necessary the help of an AXMEDIS expert to correct the problem, which was due to an obsolete external DLL; the second time the installation was easier but it took a couple of days to be

completed anyway. Another problem is that each Web service requires its own specific usage authorization and/or user authentication, resulting in either very weak username/password pairs being used (like test/test), or in the proliferation of username/password pairs. A single sign on mechanism would be very appreciated here, unfortunately this is currently lacking.

5. The AXMEDIS Content Processing (AXCP) tools – are the core tools of the Content Factory; unfortunately they are bundled in a big package (about 350 MB), but they come with an installer which makes the setup quite easy. However they must be certified before being able to manipulate protected content, and certification is performed by calling the executor with some specific parameter, and passing to it a reference of the users's certificate and a corresponding password, obtained by the user at registration time. Therefore only AXMEDIS registered users can actually install the AXCP Tools (unless someone decides to use them just for unprotected content). Moreover, also the tool itself is certified, which means that each time a new version of the tools is released, the user and tool certification must be repeated. This is not a problem now that a stable version is out, but it was quite annoying during the project life, when development was very intensive and new version of the tools were released quite frequently. Currently the last and partially unresolved problem regarding the AXCP Tool is the lack of stability of the executor (grid nodes), which is mainly due to the fact that this is the tool where all the various new featured developed by the project are integrated and used. Since the executor and the scheduler are supposed to run continuously, if they fail for any reason the services of the Content Factory are interrupted.
6. The OMA DRM Server (out of scope of AXMEDIS, reported here for completeness) is a java package that is deployed on Tomcat and implements various web services. However since it is packaged in a single "war" file it is quite easy to install and configure.

Integration of the various parts was achieved by means of five AXCP rules running on the AX4HOME server and performing respectively the following functions:

1. Rule 1 ("OMAGateway.axr"): this rule checks every day if any new content has been uploaded into the AX4HOME data base, in which case it further checks if the new content is a candidate to be published on the "music store" portal, i.e. if it is marked as being "music" and if all the required "Dublin core" values are set: title, creator, description. In this case it strips away any resource apart from the audio track, and converts the audio track to AAC format using the following parameters: sampling rate 22050, mono, 64 Kbit/s output rate, leaving the metadata untouched. The modified object is then passed to the content upload web service of the OMA DRM Server using the `HttpConnection()` class provided by the AXCP environment based on Javascript. The OMA DRM server ingests the new content, converts it in OMA DRM DCF v2 format (protected by AES encryption), and publishes it on the mobile version of the Music Store portal.
2. Rule 2 ("AXMGateway.axr"): in a similar way, this rule performs the same checks described above but does not perform any content adaptation, since in this case we assume that the content object will be delivered on a broadband channel. However it performs some operations which are needed in order to protect the object:
 - a. Adds a registration URL to the metadata information ("PARLicensingURL") which allows the AXMEDIS Player to automatically perform the registration of the user to the "Music Store" service;
 - b. Checks if the content identifier (AXOID) is registered on the central AXCS server; if not, it performs the registration;
 - c. Protects the object using AES encryption with a randomly generated 128-bit key and Initialization Vector;
 - d. Registers the protected object on the AXCS server;
 - e. Publishes the resulting protected object on the Music Shop broadband portal.

3. Rule 3 (“createAXMLLicenses.axr”): this rule checks daily if any new license must be created, and if this is the case, it creates the new licence, stores it locally, and sends a copy of the license to the central PMS server so that it starts being enforced by the AXMEDIS Tools. There can be two reasons why some new license need to be produced: either because a new content object has been published, or because a new user has registered as customer of the Music Shop broadband portal. In the first case, the rule produces a Distributor License (mother license) for that object that assigns to the distributor (the AX4HOME Factory itself) the right to issue time-constrained licenses for that object to any user, and then generated the user licenses for all users registered on the Music Shop (the list of registered users is maintained in a MySQL DB table which is readable from the Javascript rule by means of the OdbcConnection() class); in the second case, i.e. when a new user has registered as customer of the Music Shop, the rule produces a user license for that user for each content object stored in the Music Shop, just exploiting the already available distributor licenses. The licenses are created with time constraints set in such a way that they remain valid no more that 35 days (1 month + 4/5 days grace period), as required by the business logic of the Music Shop.
4. Rule 4 (“renewOMALicenses.axr”): this rule implements the “all you can eat” business model on the mobile version of the Music Shop, by upgrading the time constraint of the OMA licenses every month, in such a way that all licenses expire at the beginning of each next month. It is run each month, the first day of the month. The maximum duration of each license is 35 days.
5. Rule 5 (“renewAXMLLicenses.axr”): this rule performs conceptually the same operation than Rule 4, but achieves the result by simple removing all licenses locally stored on AX4HOME. The next run of Rule 3 will do the actual job. Therefore, it is important to schedule Rule 3 to run after Rule 5 on the 1st day of each month, as shown in the following picture.

Rule Name	AXRID	Rule Version	Rule Status	Job ID	Executor ID	Start Time	Start Date	Periodicity	Number of Runs	Installation ...	Expiration ...
renewAXMLLicenses	axcprule:4...	1	Active	3	-1	04:00:00	01/09/2008	1 Month(s)	1	2008-07-17...	2012-05-10...
renewOMALicenses	axcprule:c7...	1.0	Active	4	-1	06:00:00	01/09/2008	1 Month(s)	1	2008-07-17...	2012-04-22...
AXMGateway	axcprule:5...	1	Active	5	-1	05:25:00	05/08/2008	1 Day(s)	14	2008-07-21...	2012-04-08...
OMAGateway	axcprule:8...	2.0	Active	6	-1	04:20:00	05/08/2008	1 Day(s)	14	2008-07-21...	2012-03-05...
createAXMLLicenses	axcprule:5...	1.1	Active	7	-1	05:50:00	05/08/2008	1 Day(s)	14	2008-07-21...	2012-04-09...

Executor N...	IP Address	CPU Type	Clock	OS	Transfer Rate	HD Space	Status	Job ID	Executor ID	Cpu Usage	From	To
AX4HOME	10.0.0.100	x86 Family ...	2.99 (GHz)	Windows N...	1 (MB/s)	43.48 (GB)	Ready	-1	1	0% (20%)	10:00:00	10:59:59

Fig. 6.2 - The AXCP Scheduler running the five rules

6.1.7 Deployment

The AX4HOME Music Shop service has been implemented as a collection of services that run on three physical machines:

- The AX4HOME server: <http://ax4home.axmedis.org/>, which hosts the AX4HOME Web portal, including the two versions of the Music Shop (mobile and broadband), the AXMEDIS Data Base, the AXMEDIS Web Services, the AXCP Scheduler and Executor (grid node), and the OMA DRM server.
- The AXEPTool server, another machine which hosts exclusively the AXEPTool – this was necessary because it was found out that the AXEPTool cannot be installed on the same machine where the AXCP tools are running;

- The OCSPD server: <http://atlantis.tilab.com/>, the Online Certificate Status Protocol responder which is needed by the OMA DRM server to verify the validity of issued OMA certificates.

Furthermore, the Music Shop uses the services provided by the central PMS (Protection Manager and Support) server and AXCS (AXMEDIS Certification and Supervision) server.

6.2 Testing the Music Shop showcase

The strategy selected to test the showcase has been dual: on one side, let anybody access and try the showcase by putting it online and collecting comments; and on the other side, perform ourselves a limited number of lab trials.

The fact that all content in the showcase was protected by a time-constrained license gave us confidence that it was possible to put the content online without any risk. However we decided to use exclusively content for which we had given a free use authorization in the past or in the AXMEDIS project itself; as a consequence, most of the music tracks available in the showcase are those kindly provided by AFI (Associazione dei Fonografici Italiani), which is a partner of the project.

As documented in the AX4HOME Web page <http://ax4home.axmedis.org/>, the Music Shop showcase went online on July 11 2008, when finally all the major issues preventing a stable operation of the AXCP Tools had been solved, and was announced on an internal mailing list in Telecom Italia. Subsequently, a couple of online opinion polls were added to collect opinions on the showcase and on the AXMEDIS tools; unfortunately, most of the people had already seen the site at that time, and the period of summer vacation was approaching, so just a few votes were collected.

Meanwhile, we conducted the lab trials by asking to some technical experts to test the showcase. The people involved in this test were technically skilled but didn't know anything in particular about AXMEDIS. At the end of the test they were asked to fill a questionnaire and to comment on the showcase. The results were generally positive even though some specific points in the showcase were indicated as possible candidates for further improvement. Among this the most important are:

- The same username/password should be usable in all tools throughout the showcase (single sign on);
- The AXMEDIS registration and tool certification procedure is complex;
- The AXMEDIS Editor does not show a progress bar when uploading content;
- Usage of AXMEDIS Player/Editor behind a corporate firewall needs custom configuration of the tool, while it could use the system configuration;
- The AXMEDIS player shows an unpleasant error message when the user plays a content object for which he has no license.

The detailed test results are reported in [5] AXMEDIS-DE12-1-5-2-AXMEDIS-4HOME Demonstration Report.

6.3 Resolved technical issues

The following issues regarding the AXMEDIS tools have been found while testing the AXMEDIS tools and have been reported to the project developers. Currently all issues reported here have been solved or at least partially addressed.

1. The Editor certification doesn't work from behind a corporate firewall. When performing the initial certification the Editor tries to connect to the PMS server using the SSL protocol on port 8502, which is not the default SSL port (443). Most firewalls block the SSL exchange when it is executed on a port different from 443. I suppose the same applies to all other tools that need to be certified.
2. Access to the REL translation functions from JavaScript is disabled;
3. The AAC audio format is not supported (in any tool - the Editor, the Rule Editor, the Player);

4. The mime-type currently assigned to the mpeg-1 audio layer III (i.e. mp3) format is audio/mpeg. Instead, the AudioAdaptation.FFAudioTranscoding call of the Rule Editor requires such resources to be tagged as audio/x-mpeg (experimental). This was the old mime assignment to the mp3 format and is now obsolete.
5. The audio fingerprinting extraction function is defined as follows: `STRING AxAFPEExtract (RESOURCE InputResource, RESOURCE OutputResource, RESOURCE OutputResource2, INT32 nFeatures, INT32 frameSize, INT32 frameShift, INT32 offset);` The last parameter indicates the offset for the fingerprint calculation, however there is no way to limit the length of the fingerprint calculation (the calculation is always performed up to the end of file). Therefore we suggest to modify the call by adding another parameter named “length” which indicates the number of audio samples over which the calculation is performed. The resulting signature would then be: `STRING AxAFPEExtract (RESOURCE InputResource, RESOURCE OutputResource, RESOURCE OutputResource2, INT32 nFeatures, INT32 frameSize, INT32 frameShift, INT32 offset, INT32 length);`
6. Using the Rule Editor to extract a fingerprint from large files (wmv having size 300-400 MB), we get the following errors: “not enough free memory in system! ran out of memory!” or “bad allocation error”.
7. The user registration procedure doesn’t check for duplicated nicknames inserted by end users in the registration web page. Instead, the procedure accepts the data, then sends an email to the end user containing an hyperlink to the registration portal; however when the user clicks on the link, if the nickname was a duplicated one, the result is a misleading error message: “server error, please try again later”. Trying multiple times always results in the same error message being displayed. We propose the user registration procedure to check for duplicated nicknames in advance, and inform the end user immediately (possibly proposing a new nickname).
8. The user registration procedure does not allow the end user to set its own password. A random password is generated, which is very difficult to remember.
9. The user registration procedure sends a total of three email messages to the end user to complete, when one would be sufficient.
10. The user registration procedure requires all fields to be filled (even the fax number! not quite common for end users).
11. There is no way for the end user to unregister himself from the DB, or to change his/her own data (preferred nickname, email address, etc.)

7 Description of Use of the Rights Ontology API Within AXMEDIS (sDae)

7.1 Report of Use

In the last months, the AxIPOntology was created along with a series of adjacent elements (API, operation and monitor applications etc.). It was integrated in an AXMEDIS application belonging to the Axtools, the Contract Manager tool, and their joint operation was demonstrated successfully in Florence.

Although technically the ontology has proved to be sound, it was not possible to integrated in its fullest capacity into the AXMEDIS platform. The reason is that the ontology provides a centralized service which, has not yet has been integrated. In particular, this service should work in tight cooperation with the user and objects databases of a prospective exploitation entity but those services were developed separately and prior to the AX4Home take up making it difficult to incorporate the changes to the corresponding User and Object management modules. Independently of this, the final AxIPOntology version supports integrating user and object databases and the demonstration illustrates these using mock versions of these.

According to the specification, the following components in the AXMEDIS Framework and AXTOOLS require modifications to enhance the aforementioned integration:

- The PMS Client, so that when PARs are inserted into an Axmedis Object, role and permissions verifications are done.
- The AXMEDIS Editor (or most probably in AXOM), so that when a new object is uploaded into the AXMEDIS Objects Database, the ontology is informed of its existence.
- The DRM Editor and Viewer / or Contract Manager, so that when licenses are created, whether or not the issuer has the requisite rights and the principal is accredited to receive them.
- User and Objects databases should incorporate more information: such as the role(es) associated with which each user in the Ontology, as well as the type of IP Entity associated with a given AXMEDIS Object with respect to a user.

7.2 Perspectives

The ontology provides an additional capacity for sanctioning that operations are made according to the common IP model it represents. For a running business, adding AXIPontology services can serve to provide credibility and trust by virtue of the rules being applied indiscriminantly to all of the business' users and in a mutually predictable manner. However, the modifications pointed out in the previous section need to be applied for entities interested in adding the Ontology support in their workflow, and may imply different changes on a case by case basis. A common API base is provided to make the integration easier, and parts of the software shown in the demo can be re-used with minor changes.

In the last MPEG meeting in Hannover, answers to the call for proposals for a MVCO (Multimedia Value Chain Ontology (MVCO)) issued in the Archamps meeting of last April were received and a first industry standard working draft has been elaborated as output from Hannover. Given that the requirements issued at Archamps were largely based on the DMP RRD although not limited to it and AXIPontology also draws on the DMP, it is expected that the MVCO standard will be compatible with AxIPontology.

8 Conclusion (BBC)

This project set out to achieve a number of objectives. Central to these objectives were two themes: the augmenting of the AXMEDIS Tools and the utilization of the AXMEDIS Tool set to show how they might be used to address an emerging industrial need.

The first theme has resulted in the provision of the Protection Tool Server, an Ontology validation tool and a Device – based Domain option. These objectives have been delivered and described.

The second theme, based upon developing demonstrators to support potential new business models relevant to today's industry is addressed through the building of the OMA gateway, fed through a live AXMEDIS back office, and the development and testing of the AX4HOME recorder application.

In principle these two demonstrators can be seen as different parts of a wider infrastructure in which the home user benefits from delivery of media over Mobile, P2P and Digital TV, and the content provider uses a centralized system for the aggregation and registration of content (shown by the back office) for subsequent delivery of the content items over the OMA gateway or on the P2P distribution. Such a combined system uses AXMEDIS Tools for creation, delivery and presentation of the final content to the user. It is part of the objectives of the AX4HOME Consortium to show that such combinations of cross platform delivery is possible using AXMEDIS Technology.

The Use case analysis and architecture specification of the demonstrators was evaluated in the context of AXMEDIS in deliverables [1] and [2] and the initial prototypes and demonstrator setup reported in [3] and [4]. The testing is described in deliverable [5]

These demonstrators have been reported above as completed and where appropriate tested by non-technologists. The form and results of these tests are described in detail in the accompanying deliverable DE12.1.6.1 [5]

In addition to the objectives summarized above and met by the deliverables described, a major part of the value of the AX4HOME consortium to the wider AXMEDIS partners has been the assessment, testing and focusing of the various tool functionalities to be able to operate within the wider systems for which they were designed. It is all too easy for implementers to consider the individual tools as isolated atoms and not give priority to the robustness of any particular feature of what has become a very wide feature set. However, the building of the demonstrators to match real world applications has set a priority on a feature set and caused much debugging and optimization. It is this last ‘hidden deliverable’ which has consumed so much effort by all involved and added real value to the AXMEDIS project and its implementation of the AXMEDIS Framework.

9 References

1. AXMEDIS-DE12-1-2-1-4HOME-UseCase-and-Reqs-Analysis
2. AXMEDIS-DE12-1-3-1-Spec-of-AX4HOME-Architecture
3. AXMEDIS-DE12-1-4-1-AXMEDIS-4HOME AXMEDIS Component Integration Prototypes and Documentation
4. AXMEDIS-DE12-1-5-1-AXMEDIS-4HOME-AXMEDIS-Demonstrator-Setup
5. AXMEDIS-DE12-1-5-2-AXMEDIS-4HOME Demonstration Report.
6. AXMEDIS-DE12-1-5-3-AXMEDIS-4HOME Final Report and Success Story.
7. DMP RRD technical description is specified in “Approved Document No. 3 – Technical Specification: Interoperable DRM Platform, Version 3.1 <http://www.dmpf.org/open/dmp1103.zip>”
8. Digital Media Project. www.dmpf.org