Interactive Applications for Digital TV Using Internet Legacy – A Successful Case Study

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***Abstract*—This paper describes the development of an interactive application for Digital TV. The architectural decisions, drawbacks, solutions, advantages and disadvantages of Interactive Digital TV development are discussed. The application, an e-mail client and its server, are presented and the main considerations about its development are shown, especially a protocol developed for communication between Internet systems and Digital TV systems.**

***Index Terms*—Protocols, Digital TV, Electronic mail, Interactive TV**

I. Introduction

DEVEOLOPING software applications has always been a hard task. When new paradigms appear, new difficulties come along and software designers must deal with it in order to succeed and, maybe, establish new design and programming paradigms. This paper describes the development of an application for the new paradigm of Digital TV applications.

A. Digital Television Environment

Software applications on Digital TV may be classified on two main types: local interaction applications and remote interaction applications. The interaction on the first one is limited to the user's local domain, namely his TV set. In the second type, interaction can be taken to a higher level. The application can communicate with other machines throughout a network, not only the local TV set. In order to achieve such level of interaction, there must be a return channel available to the user, a special channel used to send data from clients to the TV broadcaster or other servers, so the user may send data back to the broadcaster's servers or other servers.

This way, applications can be transmitted to all the receivers through the broadcast network, and user data may be transmitted back through the return channel. This opens a lot of possibilities for interactive applications.

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B. The Big Players

Today there are three main Digital TV standards in the world. DVB is the European standard, ATSC is the American one and ISDB is the Japanese standard. Each one has its own characteristics, advantages and disadvantages. The European standard offers good options for interactive applications, the Japanese is very good on mobile applications and the American is strong on high quality image.

C. The Brazilian Digital Television Effort

Television is one of the main communication media in Brazil. More than 90% of Brazilian homes have a TV set, most of which receive only analog signals [1]-[2]. The TV plays an important role as a communication medium integrator in a country of continental size and huge social differences as Brazil, taking information, news and entertainment to the whole country. There are few similarities between a country man living near a small river in northern Brazil and a business executive in São Paulo besides the fact that both probably watch the same channels and programs on TV.

Considering the country's social problems, especially the digital exclusion, the Brazilian government directed its efforts to adopt a digital TV standard that could use the potential of digital technology to take some of the features and services of a personal computer to the lower classes throughout the country. Digital television is not being faced as only a technological evolution, but as a new communication platform based in digital technology for signal transmission, exploring new possibilities of services and applications.

Among these efforts on studying existing standards and proposing a new Brazilian standard [3] is the effort of developing interactive applications for digital TV. The Brazilian government organized a number of research groups, each one responsible for a specific feature of a digital TV pattern. The AIMCOR group (Interactive Applications for Commercial and Reference Digital TV Models) composed of the Brazilian research institutions Instituto Atlântico, UNIFOR, CEFET-CE and UFC was one of the groups responsible for developing interactive applications that make use of the digital technology potential that's inherent in the adoption of a digital TV standard.

II. Instituto Atlântico's Challenge

Instituto Atlântico is a Brazilian institution dedicated to research and development in technology. It was one of the

institutions in the AIMCOR group and faced the challenge of developing an application for digital TV sets.

A. AIMCOR Group's Assumptions

The activities in the AIMCOR group started almost simultaneously with the other Brazilian Digital TV research groups and took place in an environment of several uncertainties. The main ones were related to the hardware platform, operating system and programming languages that would be used by all the groups. In order to reduce the impact of these uncertainties in the project's results, some assumptions were made:

- Hardware would be equipped with features that would allow local interaction with the user;
- Hardware would be equipped with features to access the return channel, since they are necessary for remote interactive applications;
- Hardware would have little or no means at all for information persistency;
- Software development should be delayed as possible, until the definition of the programming language to be used on the project by all institutions;
- The developed applications should be tested in two middleware models: the reference model, which would be developed in parallel, and a commercial model, already available at the time.

These assumptions taken together with the challenge of understanding and developing applications without the proper test environment and the lack of technical information in the early stages of the process, built a challenging situation which made the decision process really difficult in the project's startup.

As the applications should be tested in two different middleware models, one decision, in special, was more difficult than others:

- Which commercial model would be the most compatible with the proposed reference model, yet to be developed?

It was necessary to wait for the results of the preliminary studies in order to make a choice.

B. The T-Mail client

Each institution on the AIMCOR group was responsible for developing a specific interactive application for digital TV. To Instituto Atlântico was given the task of developing an interactive e-mail client for digital TV sets. The software, named T-Mail, is an e-mail client and allows the user to receive and send electronic mail messages in the same way as we do with Internet e-mail. On its final version, T-Mail offers the following features:

- Access control through user name and password;
- Support for multiple users;
- Response time below 2,1 seconds (the time necessary for the application's client-server communication occur);
- Inbox with the following features:
  - Read message;
  - Answer message;
  - Delete message;
- Message composition with the following features:
  - "To" field;
  - "Subject" field;
  - Message body edition with support for colors and font size;
  - File attachments.

The application also achieved goals related to low memory requirements:

- Total application size (including figures): 387KB;
- As minimum required libraries as possible:
  - JavaBeans Activation Framework [4]: activation.jar;
  - Java TV API [5]: javatv.jar;
  - JavaMail [6]: mailmessage.jar;
  - XleTView [7]: xletview.jar.

C. T-Mail Server

The proposed solution demanded a high performance server with authentication using SMTP and IMAP protocols. Other feature, the most important, required for the server was to convert messages from the Internet to the Digital TV platform, working as a gateway. The server's final version offers the following features:

- Up to 2000 simultaneous connections;
- Response time (the time necessary for establishing a connection) less than 1 second, even when there are around 2000 active connections;
- Total time for packing a mailbox of 200KB inferior to 4 seconds;
- Support for authentication through user name and password;

Information log for auditing or billing.

III. CRITICAL ISSUES

Besides the issues inherent to any software development project, the development of T-Mail brought a number of issues from the context in which it should be developed. As presented in previous sections, T-Mail should be developed in parallel to the development of the main hardware platform and basic software in which it should run. Though, there was no way to test the implemented functionalities in the required environment during the development process.

The research project on Digital TV organized by the Brazilian government included the development of an Access Terminal (AT), a hardware equipment also called Set-Top-Box (STB), in which functions and basic services should be offered to the applications via a special middleware, also developed by Brazilian researchers. As the development of all these elements were happening in parallel, at the same time, the solution found by the T-Mail designers was to assume the most basic possible environment for the application's implementation. This way, the risk of falling into incompatibilities between the application and the new environment was drastically reduced, especially with the middleware, which interacts

directly with the application. Using only the basic functionalities, it was expected that at the end of the development process, T-Mail would work without major problems in the platform developed by the other research groups.

A. Commercial middleware

Preliminary studies made by all the involved research groups showed that the Brazilian standard should be an extension of the European standard, DVB (Digital Video Broadcasting) [8]. This choice was made because between all the three main digital TV standards, the American, Japanese and European, the last was the one that offered more features required for the Brazilian standard. Thus DVB was elected the commercial digital TV standard to be used in the tests of new applications.

B. Programming language

It was also decided that the applications should be developed in the Java Platform [9], which consists of a programming language, an environment for execution of object-oriented programs and a number of integrated services.

One of Java's technologies is J2ME (Java 2 Micro Edition Technology) [10], the platform's version that deals with mobile computers and embedded systems. Digital TV sets and set-top-boxes fit in the categories supported by J2ME, more specifically, in the JavaTV technology [5]. JavaTV comprises a set of libraries of Java code for the development of digital TV applications. The programming language and environment used on this technology are compatible with JDK1.1, one of the first Java versions. The main technical issue considered in this choice was the limitations and uncertainties related to the environment in which the applications should run, with little memory and low processing power.

C. Required libraries

In addition to JavaTV, the development of T-Mail demanded the following additional libraries:

- OpenMHP [11]: an open source project on the development of DVB applications;
- JavaMail [6]: a set of Java libraries for the development of applications with electronic mail features;
- JavaBeans Activation Framework [4]: an extension of the Java platform with utilities for the use of JavaBeans components.

D. Development environment

The application development took place in PCs equipped with Windows and Linux operating systems. The programming environment used was the Eclipse IDE, version 3.2.1 [12].

E. Simulation environment

The project would not have been finished on time if it weren't the existence of XletView [7], an emulator for execution and test of MHP applications on PCs. At the time of the project development, XletView wasn't a complete emulator, there were plenty of incomplete code and functionalities on it. It was necessary to extend XletView in order to test all T-Mail features.

F. Test environment

T-Mail was tested on a STB I-CAN [13], a commercial set-top-box, achieving 100% success on all final tests. The software also succeeded on the final tests executed on the reference middleware and hardware, developed on the Brazilian Digital TV Project. Some results are commented on [14].

G. Development strategies

Considering all the uncertainties in the early stages of the project, T-Mail was developed using only the most basic features of the adopted programming platform and libraries. This way, the software was designed not only to be compatible with the proposed Brazilian Digital TV standard, but also with the European DVB pattern, since no specific feature from the new standard was being used.

Other challenge faced by the T-Mail designers was related to the persistence features on the Brazilian STB. It was desired that T-Mail would be a resident application on the STB, and that the e-mail messages brought to the equipment were persisted locally, in order to save the network from unnecessary traffic. Unfortunately, at the time there were no guaranties that the STB would comprise enough persistent memory for that. So the solution was to design T-Mail in a way that it would use as little memory as possible, and its total size would be also the smallest possible, making its transmission to the STBs faster, avoiding unnecessary traffic on the digital TV network.

H. Human-Computer Interaction

The application's graphical user interface was also a challenging issue. Since T-Mail should run on any TV set or set-top-box, the graphical user interface should adapt itself to several screen sizes and resolutions. To achieve this requirement, the application's layout was designed to be calculated at runtime, fitting several screen sizes and resolutions.

Issues on the applications' appearances and user operation were intensely studied on AIMCOR group. As a result from this work, the applications came out with appropriate visual presentation and usability. Other important issue was the data input device required, a TV remote control. Consisting of some special buttons and a numeric keyboard, the digital TV remote control is not the most appropriate device for textual data input. The T-Mail designers equipped the application with special interface features to help the user find the correct mapping between the alphabet and the numeric keyboard, as seen in Figure 1.

Fig. 1. T-Mail message body composition screen.

There were also some interface elements to help users change font color and size.

IV. Solution Architecture

T-Mail's solution architecture defines three major units for the application: T-Mail Server, T-Mail Client and an internet E-mail Server, as shown in Figure 2.

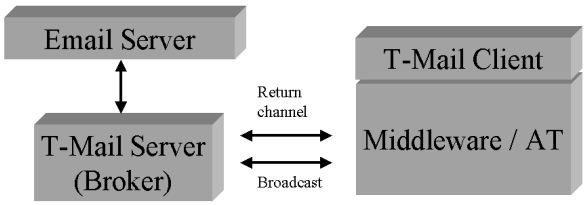

Fig. 2. Solution architecture for T-Mail.

The Access Terminal (AT), or STB, receives incoming data from the digital TV broadcast. That's how the T-Mail application is transmitted to the AT. Once at the AT, the user can run the application. At the start of execution, T-Mail asks the user for its credentials (name and password), following this sequence of actions:

- ✧ T-Mail Client activates the return channel;
- ✧ T-Mail Client establishes a TCP/IP connection with one of the available T-Mail Servers and sends the user's credentials;
- ✧ The T-Mail server authenticates the user sending its credentials to an E-mail Server;
- ✧ The E-mail Server authenticates the user;
- ✧ The T-Mail Server notifies the T-Mail Client of the successful authentication;
- ✧ The T-Mail Client allows the user to use all the applications features.

To access the mailbox, the following actions should take place:

- ✧ The user asks for access to his messages through the applications main menu;
- ✧ T-Mail Client establishes a TCP/IP connection with the T-Mail Server and sends the user's credentials;
- ✧ The T-Mail server authenticates the user;
- ✧ The T-Mail server gets all the user's messages, packages the data and sends them to the T-Mail Client;
- ✧ The T-Mail Client shows the inbox with all messages to the user.

Other operations follow a similar sequence of steps, varying only specific actions taken by the user.

The proposed architecture supports scalable growth of requirements, allowing a hierarchical data distribution organization. The organization of T-Mail and E-mail Servers can be made by region or by service providers. T-Mail server's architecture is shown on Figure 3.

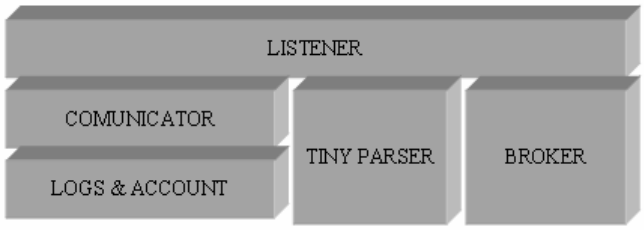

Fig. 3. T-Mail server's architecture.

The LISTENER component is responsible for connections in the T-Mail Server. COMMUNICATOR is the component responsible for data communication and transmission control. LOGS & ACCOUNT logs all the operations in the server, allowing audition and billing. The TINY PARSER receives data from T-Mail Clients through the COMUNICATOR component, which identifies the requested service and processes the request threads. Finally, the BROKER component translates messages between the format used on digital TV and several formats used on Internet e-mail servers.

A. Data encoding

In digital TV, data can go to Access Terminals through the data flow transported by the TV broadcast or through the bi-directional return channel. When a user requests an operation through an interactive application, data from this request generally will reach the servers through the return channel. Since this channel may be intermittent, the response data can be sent through the broadcast channel. If some problem occurs during the digital transmission, and some packages are missed, it is necessary to wait for the retransmission of all the packages, starting on the first one missed and discarding the ones that were not received in order. In order to save these packages and not retransmit them without real need, the T-Mail designers developed a custom protocol for packaging data that allows transmission of packages out of the order in which they were produced with no loss of information and no unnecessary use of network resources.

As there were also some uncertainties about the type of return channel and possible connections in the project, the designed protocol was made independent from the transport protocol, acting as a protocol on the service layer. Figure 4 shows the protocol's package format.

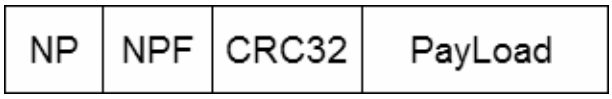

Fig. 4. T-Mail protocol's package.

The protocol package has four fields, each with a specific function:

- ✧ NP (2 bytes): the package number (identifier);
- ✧ NPF (2 bytes): number of the original package, the one which was fragmented;
- ✧ CRC32 (4 bytes): transmission control data;
- ✧ PayLoad (8 - 1000 bytes): data from the fragmented package to be transmitted.

For a complete transmission cycle, many components of the protocol are used. Figure 5 shows an example of message exchange by the protocol.

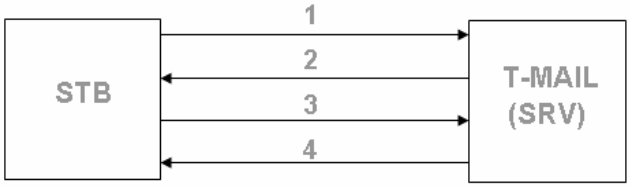

Fig. 5. Message flow of an operation on T-Mail protocol.

The flow from the example happens, between the set-top-box and the T-Mail server as follows:

1. The STB sends a request package;
2. The T-Mail server sends a confirmation message for the previous step;
3. The STB sends a package with the required data;
4. The T-Mail server sends a message confirming that it received the package from the previous step.

If some problem occurs and a package is missed, the protocol requests only the retransmission of the lost package and not the whole set of packages.

V. Conclusion

The development of the interactive T-Mail application demanded a great effort to overcome several obstacles that showed up during the process, especially on the early stages of the project. Besides all the drawbacks, the project was successfully finished and we can stress some of its positive results, like the overall comprehension of the team on this new digital TV technology; the proposal of a scalable architecture for the T-Mail application and the proposal of a new protocol for communication between Internet systems and digital TV systems.

As future works, we can envision the T-Mail application improvement by the inclusion of new features, as the option for local message storage, in case of STB's equipped with local persistent memory. The use of auto-completion techniques for message compositions would also be a very welcome improvement on T-Mail. The experience acquired on this project can also be used on the development of new applications for interactive digital TV.

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