MITv – A Solution for an Interactive TV Based on IP Multicast over Satellite

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Abstract-- **Television is the most popular audiovisual application ever used. The technological headways in digital transmissions allow new interactive services to complement classical Television broadcasts. However, the solutions available need specific infrastructures often making them hard and costly to deploy. MITv is a proposition for interactive television to be deployed using association of current distribution television systems (e.g., satellite DVB-S, cable DVB-T, TV over xDSL, etc.) and classical Internet infrastructure. MITv makes use of the natural association between broadcasted TV programs and associated interactive contents to manage replication of those contents over an ad-hoc infrastructure. The replication phase can be based on IP Multicast over satellite service, providing a high performance and realistic way to convey the interactive content over the geographically distributed replication units. The proximity between replication units and end-users then allow a very high quality for interactive media presentation by the way of an access network such as xDSL. The MITv system was entirely developed and tested in real conditions through a satellite/xDSL network emulator.**

Index terms—**IP multicast, Interactive TV, Caching, DVB, xDSL, Network emulation.**

I. INTRODUCTION

Television is the most popular audiovisual application ever used. It represents a major concern in terms of technical, social and economical matters. Digital technology is driving television services towards higher and higher quality. This technology also allows facilitating the implementation of interactive television services providing an amazing set of new possibilities, such as complementary multimedia information, electronic program guides, pay-per-view videos, etc. This context represents a great challenge and there is a trend to develop interactive services on digital television.

Obviously, if the TVs' quality has greatly evolved during the few past years, new services such as interactivity and associated media on-demand are still not really deployed. Up until the present time, various interactive television systems have been proposed and sometimes commercialized. But these systems are often based on specific infrastructure and heavy developments [1]. Looking at the macro-economic drivers for the adoption of a technology, high-value and high-quality services have to be targeted to justify the investment in a new infrastructure. But the lack of commercial success of today's solutions indicates that interactive television (ITV) does not provide sufficient services and/or remains too costly or hard to implement. Then, without concession on the high quality of service that must be offered to end-user, a low cost and a very pragmatic architecture must be defined to support these types of services.

It is now possible to implement interactive television with minor modification on today's infrastructure. Large Internet and high speed end-user access (e.g., xDSL) can provide the sufficient support to convey interactive services and on-demand data contents. Classical TV broadcast networks (e.g., satellite, but also cable or more recently TV over xDSL) are then naturally completed with Internet services. But very high Quality of Service (QoS) need to be ensured when end-user access to interactive services associated to TV broadcast. These QoS guarantees are particularly difficult to obtain when users, almost at the same time led by the broadcasted show, are brought to access interactive contents through the classical best effort Internet service. A solution may consist in managing QoS at network level using e.g., Intserv and/or Diffserv models, in modifying the best effort service of IP to offer QoS guarantees. Those techniques are possible to implement in a restricted environment. However, various difficulties such as scalability, interoperability or commercial agreements complicate noticeably the deployment of those proposals to global Internet. Considering a logical synchronization between a TV-broadcast and associated on-demand multimedia contents and/or interactive services, it is possible to predict the future network utilization. This prediction can be used to deploy and replicate contents and services in strategic points on the network at the right time. The end-users are then able to access the interactive contents and services with a high QoS.

In the present study, we propose a high service quality with a low cost solution for Interactive Television based on replication. This system named Multicast Interactive Television (MITv) is build over an IP multicast service over a DVB satellite system. With MITv, television broadcast can be conveyed by classical DVB-S channels, but also by other techniques such as cable or TV over xDSL. At the same time interactive content is replicated near the end-users on geographically distributed replication servers using IP multicast over satellite service. Users can then access on-demand interactive contents and services by the way of high speed Internet access, using for example xDSL technology. A performance of this system could be as follows. In a talk show, while presenting guests' current events (movies presentation, deliver, etc.), the replication units could have been loaded with a set of associated contents such as film trailers, book summaries, author

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biographies, etc. The multimedia contents could also be completed by a purchase service, with on-line payment services stored in replication entities during the broadcast. In concordance with a predefined timing; the end-user would be alerted by specific triggers that interactive media is available.

The broadcast nature of satellite systems make it a pragmatic solution (cheaper than terrestrial diffusion for large groups) to implement IP multicast service. Indeed, it allows conveying interactive contents and services to a large number of replicated caches with almost only one hop. Moreover, as end-users can access additional contents at known predefined times, cache management is really efficient. The rest of the paper is structured as follows: Section II presents the satellite context which is particularly interesting for interactive television. Then MITv system architecture is proposed in section III. Section IV proposes an implementation and an emulation-based performance study of the system, showing that the expected high QoS is obtained. Section V finally concludes the paper.

II. SATELLITE AND INTERACTIVE TELEVISION

Satellite transmission systems using MPEG2/DVB [2][3][4] technology are widely spread today and constitute a well mastered technology for TV distribution. In particular DVB technology is considerably used in Europe for broadcasting TV channels with satellite (DVB-S technology).

New satellite systems that offer IP or IP Multicast services are currently studied, see e.g., [12]. Major headways have been done on "On Board Processing", (OBP), allowing a satellite to process data on board. This technology permits to switch data over various small geographical spots instead of globally broadcasting data over the entire coverage zone. This technology facilitates frequency reutilization and allows throughput and power optimization. Nevertheless, due to their long propagation delay and processing time, networking services based on geostationary satellite systems are particularly devoted to IP multicast applications with weak time constraints [5].

Due to the natural broadcast capacities of satellites which allow reaching a potentially large number of receivers in one hop, broadcast and multicast applications such as television and multipoint file transfer are particularly well supported.

In this context, recent developments of TV and digital technology make interactive television possible, combining *Traditional TV* with interactive content and enhancements. Many solutions were used to implement ITV. In a large part of Europe, people have used interactive services in the textual form of "Teletext". As communication infrastructures evolves, ITV moves to a new interactive experience based on *set-top, box-based or 2-screen TV*, where people can see the call for interactivity during the show and go to computer or use mobile phone or PDA to interact with the show. Many new ITV systems are based on the principle of on-demand TV or Web TV [6] [7]. Other ITV systems largely deployed are based on available "Interactive TV-Guide" or "carrousel" periodically broadcasted over cable and satellite channels [8]. These solutions are particularly greedy in term of satellite resources and the services proposed are limited to static multimedia data browsing.

III. MITV : MULTICAST INTERACTIVE TELEVISION

MITv is an interactive television system based on the coupling of traditional digital video broadcast distribution services (e.g., MPEG2/DVB) and multimedia contents replication using IP Multicast support. The interactivity in this context consists in allowing the final user to access associated data and services. The contents replication near end users provides communication support for strong service interactivity as well as a good presentation quality for multimedia contents.

MITv is constituted of three complementary parts: the production unit, the communication and the user systems. We describe first the communication system.

A. Communication system

In regards to broadcasted TV that uses classical TV broadcast networks, end-users must be aware of the availability of interactive content (IC). This indication is provided by triggers that logically associate a specific TV program or sequence to multimedia contents. Those triggers are conveyed from production server to the set of final MITv receivers and then presented in incrustation on the TV screen. IP multicast over satellite service is used to transport those triggers that are then forwarded to the access networks to reach the end-users. Once a Trigger indicates the presence of contents, the viewer is authorized to access the IC.

An important constraint of MITv system is to ensure the high level of presentation quality for IC. This objective can be reached by ensuring high QoS guarantees in the communication system that delivers the content. Due to the best effort service of classical Internet, these guarantees cannot be ensured. Moreover, the overall end-user request synchronization due to the trigger multicasting increases noticeably the congestion probability on network routers and servers that are delivering the data.

MITv system faces this problem by feeding contents replication and distribution units (CRDU) distributed on the broadcasting zone and close to end users. Those users are then connected to the CDU by a high speed access network such as LAN Ethernet or xDSL technologies as shown in Figure 1[1].

The access network is supposed to offer a sufficient QoS for IC distribution. These guarantees, easier to provide in the local network environment than in the global Internet, can be implemented either by local QoS management (IntServ) or by resources over-provisioning.

[1] Note that in the Figure, Digital TV is broadcasted using classical DVB-S to end user Television receivers but this could be also distributed using cable TV or TV over xDSL or technology using the wired access network.

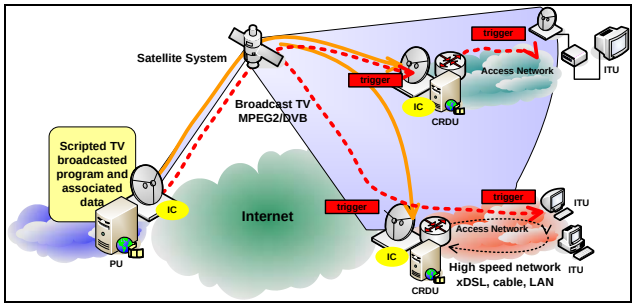

Figure 1. MITv architecture for Interactive TV

The IP multicast service is used to replicate the IC over the set of CRDU. This replication is made on the basis of an interactive program specification (see section III.B) that specifies all the information needed to decide what and when to replicate. Considering the transport of an IC using the best effort IP Multicast over satellite, a fully reliable transport protocol must be used. Moreover, to be efficient, the protocol must be expressly designed for a satellite link. MITv software has been architectured to allow the use of various protocols. It has been tested with raw UDP, RAMP [9], and FCAST/ALC [10]. However those protocols are not specifically designed for a satellite environment. In particular they don't consider long delay, packet loss distribution and expensive bandwidth of such a transmission. Keeping those characteristics in mind, an efficient solution for transport layer consists in broadcasting information only when the set of receivers is sufficiently large so that it is advantageous. Then when satellite transmission stops, the remaining receivers (i.e. receivers experiencing high loss rates) should retrieve lacking data with terrestrial network. This hybrid Satellite/Terrestrial solution, particularly adapted to the MITv environment (communication architecture, large group, etc.), is currently studied [5].

B. End systems

As shown in Figure 1, end systems of MITv consist in the Production Unit, Replication and Distribution Units and Interactive TV Unit. Interactive TV is specified and scheduled in the Production Unit and transmitted to the communication system. Replication and Distribution Units allow the local caching of interactive content, and Interactive TV Unit allows the end-user to watch TV and browse associated interactive services.

The production unit (PU, see Figure 1) allows the entire specification of the interactive television program. It associates broadcasted and interactive contents. The IC specification contains a set of information allowing to decide how to process it, e.g, QoS constrains to present it, the geographical area to multicast it (e.g., depending on language used), etc.. It uses a XML based description based on the XQoS language [11]. This specification allows taking into account how, what and where to replicate content over the delivery network infrastructure. As mentioned earlier, each association is implemented using a "Trigger" designed to make a logical link between the TV broadcast and the IC. This logical link is exploited, on one hand, to decide on the pushing of the IC over a group of CRDU and, on the other hand, to warn the television viewer of the IC's presence. A scheduler uses the interactive program specification to submit the various contents types over the communication system (TV broadcast, IC, and triggers) up to the CRDU and end users.

The user system manages interactions between the end user and the interactive television system. It is responsible for the display of information (TV broadcast, "Trigger", and IC). It also manages the user commands allowing him to show the IC.

ICs are a set of multimedia data to be distributed over the CRDU, and occasionally services allowing their distribution. Typical examples of associated multimedia contents are a Web site containing HTML pages and images, an audio or audiovisual document. The QoS required by each type IC for the distribution to end users can be summarized as follows in Table 1.

Medium	Bandwidth	. Delay	jitter	Reliability
IC(web)	50 kb/s (10 to 100kb/s)	150ms	50ms	Total
IC(audio)	175 kb/s	150ms	30ms	Total
IC(audio+ video)	500 kb/s	150ms	30ms	Total

Table 1. QoS required for IC distribution access.

In such a way to provide sufficient QoS access to end-users; a CRDU is necessary on each high speed access network. Then, CRDU is fed by the IP multicast over satellite service according to Interactive Program Specification. Each CRDU is simply constituted by a set of servers according to the data stream they have to provide, e.g., web server, multimedia streaming servers, etc.

Finally, the Interactive TV unit is able to present classical audiovisual TV stream. It must also provide a way for users to browse and use the various IC associated to the TV broadcast using the access network and TCP/IP protocols.

IV. IMPLEMENTATION

A. Development and Test

We develop MITv in JAVA (JDK 1.4.1) using both Java Media Framework (JMF) and QuickTime 6.0 for JAVA library within the framework of the DIPCAST project [12] (national RNRT project: IP Multicast over DVB-S/DVB-RCS system). CRDU were implemented with Apache and Darwin streaming servers. The ITVU graphical user interface is shown in Figure 2.

We experiment the application and then check whether MITv faithfully respects the network constraints which have been previously presented. Various networking environment enabled to carry out those experiments: operational networks, simulated network and emulated networks. Test over operational network environments are particularly costly and hard to implement. The use of simulation requires system modelisation including

applications, communication protocols and physical infrastructure. As a result, emulation can be viewed as a good compromise between simulation (a controlled, reproducible environment, allowing a rapid and easy implementation) and operational network (i.e., use of "real code" for the end-systems).

Figure 2. MITv Control Panel

Experimentations have been carried out using a Network Emulator platform called NINE (Nine Is a Network Emulator). NINE manages a large set of end-stations and is able to reproduce a specific network service between those stations. It is based on the Dummynet emulator [13] running FreeBSD and a set of software allowing the overall platform configuration and experiment controls. NINE has been used to reproduce satellite and ADSL network conditions in real time. A dynamic emulation model based on a set of rules defines how the emulator had to constraint the traffic between the various end-systems in term of delay, bandwidth and packet error rate. The following figure shows the emulation model developed for the specific environment of DIPCAST network.

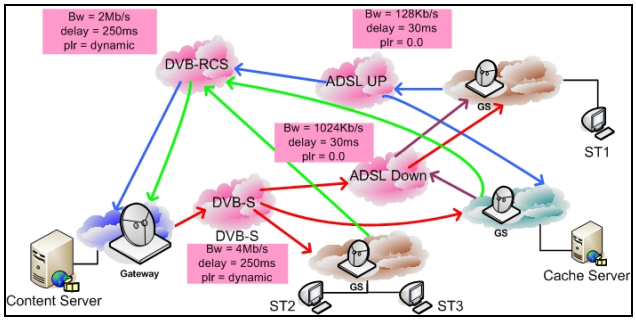

Figure 3. Emulation view of the MITv system.

The satellite system studied in DIPCAST is a two-hop system, i.e. communications between different sub networks have first to go through the Gateway. For example, suppose that host ST1 send a message to host ST2, packets first go through the ADSL UP pipe where upstream ADSL QoS is applied. Then data packets are routed through the DVB-RCS pipe with a specific dynamic QoS model, before they are forwarded towards the DVB-S pipe and finally reach ST2.

B. Performance Study

A number of experiments have been carried out on NINE with the conditions previously exposed. The following results have been obtained from exchanges of different types of data between various end-systems (caches, users, etc.). The first results are presented in the following table.

Medium	Bandwidth	Delay	Reliability
IC(web)	53Kb/s	41ms	Total
IC(audio)	133 Kb/s	41ms	Total
IC(audio/video)	874Kb/s	41ms	Total
Caching feeding	1562Kb/s	302ms	Total
Triggers	4.82Kb/s	344ms	Total

Table 2. Performances resulting from emulation

Thanks to measurements, we can notice that this solution allows final users to access available data with a good QoS. Moreover, all the requests of the clients are sent to caches and consequently do not cross satellite system. Thus this solution is scalable since the number of final clients does not involve extra loads for the satellite link, considered to be the critical resource of the whole system.

V. CONCLUSION

In this paper, we present MITv, an interactive television system based on IP Multicast. The proposed system provides a scalable performing high quality service based on current technologies such as TV broadcast, local access networks and Internet protocols. Development and tests demonstrate the feasibility and the advantageous performances of such a system.

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