SIP Based IPTV Architecture for Heterogeneous Networks

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***Abstract*—Abstract—This paper presents an IPTV service architecture using Session Initiation Protocol (SIP) for session and media control and based on the IP Multimedia Subsystem (IMS) concept.**

The proposed IPTV architecture is suitable for scalable converged networks, like flexible multimedia delivery of personalized streams over a variety of channels and networking infrastructures, including mobile networks.

A new Quality of Service (QoS) adaptation method allows dynamic updates of session parameters, in order to maximize the Quality of Experience (QoE) and turning the solution suitable for live multimedia streaming, independently of the cast mode (unicast or multicast).

The details of both the IPTV Application Server and the IPTV Client prototypical implementations are described, as well as the results of field tests carried out across different Fixed and Mobile access networks.

***Index Terms*—IPTV, IP Multimedia Subsystem, SIP.**

I. Introduction

The implementation of Internet Protocol (IP) technology over many access technologies, such as Digital Subscriber Lines (xDSL), 3G Mobile networks and Cable networks (DOCSIS) [1], has allowed a convergence of data services on all fronts.

Due to IP technology, operators have started to offer Triple-Play services: a bundle of voice (telephony), video (television) and data services along with some value added services, using one common technology [2], either in mixed mode or in All-IP mode.

From the All-IP video perspective, the Internet Protocol Television (IPTV) is the technology that provides real-time digital video streaming and television services, over managed IP core and access networks, with mechanisms to ensure appropriate quality of service (QoS) and experience (QoE), interactivity and reliability [3]–[5].

The International Telecommunications Union (ITU) has defined a reference model for the IPTV Next Generation Network (NGN) architecture. The architecture considers four main roles [3] that may pertain to separate entities, for example, the content provider may be a media organization, the service and network provider may be an operator and together they serve the customer with IPTV services. A description of the roles are as follows:

- *Content Provider:* This entity owns or sells the content to be streamed to the Customer.
- *Service Provider:* The IPTV service is provided by the Service Provider, the content is licensed or acquired from the Content Provider. The Customer buys the service which is a package that the Service Provider creates from available content.
- *Network Provider:* The connection between the Service Provider and the Customer is assured by the Network Provider.
- *Customer:* This entity purchases and consumes the IPTV service.

In terms of convergence, the IP Multimedia Subsystem (IMS), originally designed by Third Generation Partnership Project (3GPP) and later updated by 3GPP, 3GPP2 and TISPAN [6] is considered the "de facto"' architecture for many within the telecommunications industry [7] and presents itself as the framework that allows the convergence of the Internet, wireless and wireline networks and the global platform for the delivery of IP multimedia applications in NGN. This All-IP network architecture is access medium independent and based on packet based networks [8].

By providing an interactive and unique platform for multimedia distribution, IPTV enables the creation of innovative services that may be used as building blocks for future IPTV's *killer application* [1]. These services are:

- *Broadcast Television* - Traditional television, multiple–view television and subscription services (pay-per-view), in standard (STD) or high definition (HD) and electronic programming guide (EPG);
- *On request services* - Video and music on demand, respectively VoD and MoD;
- *Public interest* - Emergency broadcasts, information and news feeds;
- *Advertising* - Segmented and interactive advertising, on request advertising (such as movie trailers);
- *Interactive services* - Communication (e.g., social networking, instant messaging and e-mail), general information (such as Weather forecasts and Fora), commerce (e-Commerce and Online Banking) and entertainment (such as games and blogs);

The IPTV service requires a signaling protocol in order to initiate, modify and terminate sessions. The IPTV service also requires a control protocol that introduces networked *Trick Functions* similar to those found on

[1] *Killer Application* - a feature, function, or application of a new technology or product that is presented as virtually indispensable or much superior to rival products.

personal video recorders (PVR) such as PLAY, PAUSE, REWIND and FORWARD for the interactive control of multimedia streams. Finally, the IPTV service relies on transport protocols, responsible for transporting the multimedia streams to the end device, be it a set-top-box (STB) or a mobile device.

The Session Initiation Protocol (SIP) [9] is the "de facto" protocol for signaling and session control in IMS. It may be defined as a very flexible protocol for managing multimedia sessions over IP. A SIP session can include any type of media and any type of application. Therefore, a SIP session permits sharing a service context between a user and an application, or between two or more users. Each service within the SIP session can use its own protocols, and SIP is just setting the framework for these protocols to be used between various endpoints [8], [10].

This paper presents a novel architecture for providing converged SIP based IPTV services in IMS environment and shares the experience of the development and evaluation of such IPTV service architecture, realized within the scope of the european project *My eDirector 2012* [11] and respecting the requirements specified by a portuguese 3G CDMA2000 mobile network operator. The paper describes the details of both the IPTV Application Server and the IPTV Client prototypical implementations. Several tests were carried out with the developed IPTV system, using high-bandwidth LAN connections and a 3G CDMA2000 wireless network.

In this paper, Section 2 describes related work and Section 3 presents the proposed architecture of the IPTV Application Server system and the IPTV Client. Section 4 presents the performance evaluation of the solution. Section 5 concludes the paper.

II. Related Work

There are two main modes offered in IPTV services, the continuous streaming and the Video on Demand (VoD) content streaming. Continuous streaming is analogous to traditional television distribution where a live channel is broadcasted to the viewer. The viewer has to join an ongoing stream in order to watch its contents. Video on Demand, as the name suggests, allows the viewer to request pre-stored video contents. Due to the underlying bidirectional communication capabilities of IPTV, it can provide interactive sessions, using either of the streaming modes, to create a plethora of derived services and allow viewers to manipulate content and actively participate during sessions.

But providing multimedia services requires stability and reliability in order to maximize the Quality of Experience (QoE). To respect these requirements several techniques can be applied to maximize the usage of the transmission channel, such as video and audio compression (through codecs), transport, control and signaling protocols and efficient streaming architectures [12].

For real-time based applications, like IPTV, the goal of QoS is to keep a reduced level of control over the current "best-effort" service provided by typical IP networks. [13]. In order to provide video services with end-to-end QoS support there are two main approaches: provisioning from a network perspective and from the end-systems' perspective [14]. End-system centric mechanisms to provide end-to-end QoS support include, among other techniques: error, congestion and power control (in case of wireless networks) as well as more efficient multimedia encoding technologies. The goal of these techniques is to maximize QoS whilst not requiring any core network QoS techniques. This minimizes changes in the network, but requires highly efficient control mechanisms.

These were the main drivers for the IPTV architecture presented in this paper.

III. Proposed Architecture

This section presents the proposed IPTV architecture for both the IPTV Application Server and the IPTV Client as well as the SIP Signaling Structure and the Dynamic QoS adaptation method implemented.

A. Overall Architecture

The signaling functions are the core of the IPTV service. Along with session control, they allow the implementation of special features for media control that are used by the IPTV Client.

The signaling structure is based on SIP. Even though the main objectives of SIP are on session establishment and tear-down, the versatility of the protocol provides standard messages that are suited for real-time communications applications. Services such as Voice over IP (VoIP) and Instant Messaging (IM) also rely on SIP for that purpose.

For the implementation of the proposed IPTV architecture prototype, all standard SIP messages were used without the need for extensions or development of new message types. This ultimately allows existing SIP client implementations to interact with the IPTV system prototype.

The IPTV Application Server (IPTV AS) is aimed to connect to an IMS network core. As such, streamed content is supplied by Content Providers and its transmission to the Customer is assured by Network Providers.

B. The IPTV Application Server

The IPTV AS main functionality is focused on providing service establishment, control and termination.

The IPTV AS architecture follows a modular design facilitating the implementation of new functionalities. An example of such future functionalities might be the addition of a context-aware module for dynamically changing video streams based on content or Customer preferences.

The IPTV AS design also caters for scalability, in terms of both load and multimedia encoding processes distribution.

The IPTV AS tackles for load distribution by spawning a process for each IPTV Client that establishes a session. Each process handles all session control between server and client, and terminates after the client-server session is closed. Process spawning allows the implementation of clusters, by distributing processes over several machines, dramatically increasing the horizontal scalability [15].

As the multimedia encoding of video streams are resource-heavy processes, the encoding processes distribution of the IPTV AS is done in two scenarios, a Per-client encoding stream and a General Purpose encoding stream:

- *Per-client stream* – The Per-client stream provides high adaptability to clients requests but is a very high resource consuming process. For N clients connected to the server, there are N encoding processes running. This solution allows a wide set of combinations for service attributes and client control, freely defined for each client process (such as multimedia codecs, frame rates, group-of-picture sizes, etc.). This scenario is appropriate to VoD content transmission.
- *General Purpose stream* – The General Purpose approach provides high scalability but at a cost of a smaller set of available options for service attributes and client control. A fixed amount of encoding processes is running at any given time and clients have to select one of the encoding schemes from the available pool. This scenario is well suited for live content transmission as each stream is being watched simultaneously by one or more clients. From an implementation perspective each scheme must be predetermined on the server prior to any client request.

1) IPTV AS Modules: The main components of the IPTV AS are the Server Block and Session Block.

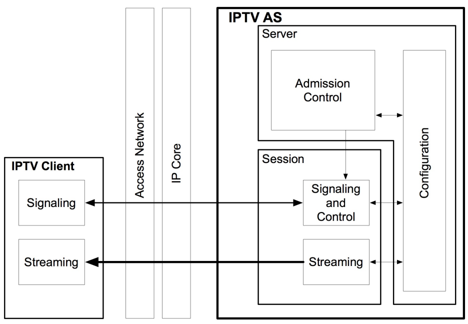

Figure 1. The IPTV Application Server

Server Block – This block provides server configuration and control and acts as the primary anchor for connecting clients. This block is composed of the following sub-blocks:

- *Configuration Block* – This sub-block is responsible for the configuration of server properties. For the General Purpose stream, provides clients with the attributes of the available streams. For the Per-client stream, provides available streaming attributes for each client process.
- *Admission Control Block* – This sub-block is responsible for the creation of a new client session whenever a new client connection request arrives. These new sessions are then handled by the Session Block.

Session Block – The Session Block, is a Per-client instance that provides the service to clients. This block is composed of the following sub-blocks:

- *Signaling and Control Block* – This sub-block is responsible for the session setup, control and subsequent tear-down. This sub-block provides the signaling and control for all IPTV *Trick Functions*. Additionally, the multimedia adaptation requests from clients are processed in this block, which in turn, signals the Streaming Block to perform the updates.
- *Streaming Block* – This sub-block provides the streaming functionalities necessary for the acquisition and transmission of multimedia content and implementation of the *Trick Functions*. If a Per-client stream is needed, it encodes and streams the content according to specifications defined by the session parameters. Client request updates are processed in this block (seamless transitions between quality levels or content stream changes).

C. The IPTV Client

The Customer terminal device runs an IPTV Client application composed by a multimedia streaming client with IMS compliant session control functions and media control functions.

The IPTV Client is compliant with the ITU-T vision of IPTV on IMS based NGN architectures.

The IPTV Client application follows a modular design facilitating the implementation of new functionalities or enhancements to existing functionalities just by upgrading the modules.

The ability to dynamically adapt to different network conditions is implemented in the IPTV Client by a special QoS monitoring module. This module collects network statistic data during the session (e.g., latency, packet loss, jitter) allowing the client to react to network conditions by setting the adequate attributes for a session update request to the IPTV AS, in order to maximize the QoE. The adaptation method by QoS monitoring and session updates is performed automatically in real-time, without Customer intervention, and without interruption of the program being watched. This new QoS adaptation method has the advantage of being lightweight and not requiring QoS support from Network Elements.

On a session setup, the IPTV Client starts by fetching the addresses of the serving nodes (IPTV AS) and the contents available for the Customer profile. Each content can be associated to a live channel, an available video or a specific point of interest (camera, actor, scene, etc.). To watch the program the Customer selects the desired content and the IPTV Client start a session with the IPTV AS for that content. The IPTV AS answers and if the content is available starts streaming it to the client.

While watching a program the client can personalize the stream by selecting a different point of interest (if available) the visual quality level, a different live channel or program and use *Trick Functions* e.g., PAUSE, PLAY, re-PLAY and STOP.

The following functionalities were implemented on the IPTV Client:

- Program Selection
- Play – Starts the session and plays the selected content.
- Pause – Temporarily pauses content reception and re-Plays from the same point onwards when desired. This function allows short pauses by means of a local buffer - *Time Shifted TV* - or long pauses but with interruption of the flow content.
- Stop – To stop playing the selected content and finish the session.
- Channel/Program forward and reverse – For live content corresponds to multicast group changes with session update.
- Dynamic session change – Session quality level is updated based on network conditions monitoring, without interruption of the program being watched.
- Manual quality level change - Customer determined quality level changes, without interruption of the program being watched.
- Real-Time session information - Presentation of session and program information, i.e., program name, stream quality, data rate, audio and video codecs.

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1) IPTV Client Modules: The IPTV Client modules that interact directly with the IPTV AS are the Signaling, the RTP Extractor and the QoS monitoring Modules.

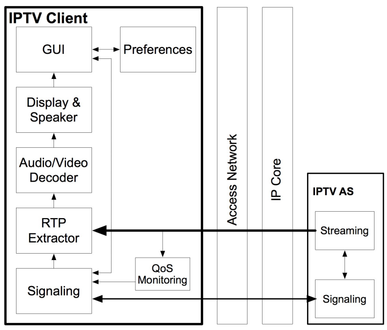

Figure 2. The IPTV Client

Signaling Module – This module is responsible for the session setup, control and subsequent tear-down. This module also provides the mapping for all IPTV *Trick Functions* and Customer Preferences from the Graphical User Interface to media control messages. Another important role of this module is the session quality update signaling, used for the dynamic adaptation of session attributes by interfacing with the QoS Monitoring Module.

Preferences Module – This module manages the Customer Preferences information.

RTP Extractor Module – This module is responsible for the reception of the RTP packets and the extraction of the RTP/NAL (Network Abstraction Layer) unit packages for the decoders.

QoS Monitoring Module – This module is responsible for the analysis of QoS metrics (e.g., latency, packet loss, jitter) and determination of policies for the dynamic QoS adaptation, together with the Signaling Module.

Audio/Video Decoder Module – This module implements the decoding processes for the audio and video contents.

Display and Speaker Module – This module provides the audio and video output driver functions for the Customer terminal device.

Graphical User Interface (GUI) – The User Interface implements a standard windowed environment with visual control buttons for the IPTV *Trick Functions* and Customer Preferences.

D. IPTV Signaling Structure

The service signaling structure of the IPTV system prototype is based only on SIP for both the session and media control.

Within an IMS based IPTV environment, this model for service control plays a major role on advanced service capabilities by introducing the set of *Trick Functions* to the user.

There is a clear advantage on this model when compared to hybrid models of SIP in combination with the Real Time Streaming Protocol (RTSP) [16] for both the signaling and media control: the simplicity of integration of the IPTV services with other session oriented services based on SIP, for example, VoIP.

Another advantage is the reuse of functions and attributes already available on SIP and Session Description Protocol (SDP) [17] to implement the media control functions, avoiding the design of extensions to SIP.

For that purpose the SIP UPDATE [18] message with different attribute values was used.

The main sections in the Signaling structure are: session establishment, session control, session quality and session tear-down:

Session establishment – As the name implies, this section is responsible for session setup. The general procedure of the protocol is similar to the one used on VoIP applications.

The content of the session INVITE message is shown in Figure 3.

The IPTV Client sends a SIP INVITE message to the IPTV service, which is forwarded by the core IMS Call Session Control Function (CSCF) to the IPTV AS (see Figure 5). This SIP INVITE message contains the SDP initial session parameters, such as frame rates and codecs to be used, as well as the Uniform Resource Identifier (URI) of the selected content. This URI corresponds to a multimedia content, such as a file located in a video repository or a live multimedia transmission.

The IPTV AS replies with a SIP 180 Trying response and checks whether the resource is available and if session parameters can be sustained. If so, the IPTV AS proceeds with the reservation of the resources and sends a SIP 200 OK message to inform the IPTV Client that the session is established and the RTP flow is started. In case the resource is unavailable (due to a wrong resource identifier, deleted content or unsupported codec), the server sends

```
INVITE sip:Lost.mp4@pipa.inov.pt SIP/2.0
From: <sip:client-iptv@84.39.2.82>
To: <sip:server-iptv@pipa.inov.pt>
CSeq: 1 INVITE
Content-Type: application/sdp
Content-Length:   415
v=0
o=SIP Server/Proxy 123 123 IN IP4 84.39.2.82
i=SIP IPTV Client session description
c=IN IP4 84.39.2.82
t=0 0
m=application 9 TCP/SIP sip
b=AS:300
a=connection:new
a=setup:active
a=quality:6
a=framerate:23
a=fmtp:media uri=sip:Lost.mp4@pipa.inov.pt
m=audio 1234 RTP/AVP 97
a=recvonly
a=rtcp:0
a=rtpmap:97 mpga/90000
m=video 1234 RTP/AVP 96
a=recvonly
a=rtcp:0
a=rtpmap:96 mp4v/90000
```

Figure 3. Session Setup INVITE Message

one of the SIP 400 failure responses and the session is finished with a SIP BYE message.

Session control and update – Session control allows the server to change session attributes without impacting the state of the SIP dialog between the client and server. This is accomplished with SIP UPDATE messages. When issued from the server side, an UPDATE allows the callee (client) to update session attributes (such as available encoding options). From the client side it implements *Trick Functions* to update the state of the media being received (such as playing or paused). The SIP Update should contain a SDP message [18].

The content of the session Control UPDATE message is shown in Figure 4.

```
UPDATE sip:Lost.mp4@pipa.inov.pt SIP/2.0
From: <sip:client-iptv@84.39.2.82>
To: <sip:server-iptv@pipa.inov.pt>
CSeq: 3 UPDATE
Content-Type: application/sdp
Content-Length:   415

...

m=video 1236 RTP/AVP 96
a=inactive
a=rtcp:0
a=rtpmap:96 mp4v/90000
```

Figure 4. Session control UPDATE Message

Session Control can be accomplished during or after the session establishment phase. For a PAUSE the client sends a SIP UPDATE message with the attribute a=inactive for the RTP/AVP streams. The server attempts to apply the requested updates to the session parameters and, if successful, responds to the client with a SIP 200 OK message. If the parameters cannot be applied, the server replies with a non-200 SIP message, such as 415 Unsupported Media Type or 420 Bad Extension messages.

To resume the session the client sends another SIP UPDATE message with the attribute a=recvonly for the RTP/AVP streams.

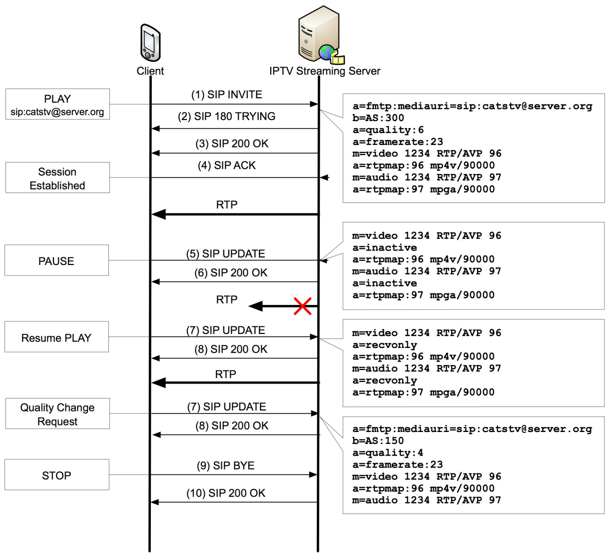

Figure 5. Example of a session message sequence

Session Quality monitoring and update – The session quality is monitored only by the IPTV Client. The dynamic QoS adaptation is accomplished by also using SIP UPDATE messages.

The content of the session Quality UPDATE message is shown in Figure 6. The session Quality UPDATE message is sent by the client with an explicit SDP quality stream attribute a=quality:xx, with a value between 0 and 10. The IPTV AS interprets the message and adapts the transmission rate accordingly, without breaking the session. There is a visual impact with the change in quality of the video stream but the session is not compromised. This method was based on QoS negotiation for IPTV using SIP described in [19].

```
UPDATE sip:Lost.mp4@pipa.inov.pt SIP/2.0
From: <sip:client-iptv@84.39.2.82>
To: <sip:server-iptv@pipa.inov.pt>
CSeq: 3 UPDATE
Content-Type: application/sdp
Content-Length:   415

...

a=quality:4

...

m=video 1236 RTP/AVP 96
a=recvonly
a=rtcp:0
a=rtpmap:96 mp4v/90000
```

Figure 6. Session Quality UPDATE Message

Session Tear-down – The session tear-down is a two stage procedure. The requesting party, either the client or the server, sends a SIP BYE message that is accepted or rejected by the other party. If the receiving party decides to end the session, all of its resources dedicated to the session should be terminated.

The content of the session tear-down BYE message is shown in Figure 7.

On the requesting side, after receiving the BYE response, all resources dedicated to the session should also

```
BYE sip:Lost.mp4@pipa.inov.pt SIP/2.0
From: <sip:client-iptv@84.39.2.82>
To: <sip:server-iptv@pipa.inov.pt>
CSeq: 3 BYE
Content-Length: 0
```

Figure 7. Tear-down BYE Message

terminate. If the BYE response is rejected, the originating party should retry to end the session by resending another BYE message.

E. IPTV Dynamic QoS adaptation

The Dynamic QoS adaptation method is based on Client side session monitoring only, without requiring any QoS provisioning at the network level.

The proposed QoS adaptation method allows dynamic updates of session parameters, in order to maximize the QoE and turn the solution suitable for live multimedia streaming, independently of the cast mode (unicast or multicast).

On the server side this means that the number of different quality streams at any moment in time is also independent of the cast mode.

The aim of the stream management at the IPTV AS is to maximize a function Q that represents the sum of quality of all streams Q_i active at one instant.

$$Q = \sum_{i=1}^{N} Q_i \tag{1}$$

As the quality of a stream Q_i is a monotonic function of the stream bitrate R_i, increasing with it, the previous function can be written as:

$$Q = \sum_{i=1}^{N} f(R_i) \tag{2}$$

Assuming that all users have equal rights, another objective of the stream management is to avoid big differences in the quality experienced by the different users, trying to minimize the possibility that one user gets a good quality at the expenses of another. This objective can be expressed by minimizing the variance of the quality of all streams:

$$varQ = \frac{\sum_{i=1}^{N} \sqrt{(Q_i - Q_{av})^2}}{N} \tag{3}$$

where

$$Q_{av} = \frac{\sum_{i=1}^{N} Q_i}{N} \tag{4}$$

The stream bit rates are subject to several constrains, namely that each stream is required to have a minimum quality Q_{min}, which relates to a minimum bitrate R_{min}:

$$Q_i \geq Q_{min}; \qquad R_i \geq R_{min} \qquad (i = 1 \text{ to } N)$$

Another constrain is related to the Encoder processing power which is limited, and can be expressed by:

$$N_{stream} \leq N_{max}$$

Based on the previous analysis, the following rules for stream management apply:

1) If the number of active streams exceeds N_{max}, one or more streams have to be switched to next existing stream of the same channel with lower quality (lower bitrate).
2) If the number of active streams exceeds N_{max}, the streams that should be stopped are the ones that are used by a low number of users. This rule is better understood if we express Q by the following expression where K_i is the number of users using stream Q_i:

$$Q = K_1 * Q_1 + K_2 * Q_2 + \cdots + K_N * Q_N \tag{5}$$

Consequently, if a stream is used by few users, its impact on the overall quality is lower if this stream is reduced to a lower quality stream, instead of a stream used by a large number of users.

3) If the number of active streams exceeds N_{max} and there is an equal number of users of two or more streams, the streams that are stopped and switched to lower quality should be the ones with higher bitrates, as this will contribute to reduce quality variance.

All previous rules should be checked in order to apply the ones that maximize Q and minimize $varQ$, in all cases.

F. Architecture Limitations

The architecture of the prototype provides a rich set of functionalities, but also a few shortcomings that may be overcome with future enhancements.

The main disadvantage of this architecture is the centralization of the IPTV Application Server, even with clustering, all content streams for clients are sent from one cluster of machines. This is due to the Streaming block being attached to the Session block. This can be partially solved by delegating the Streaming blocks to independent media servers, but this implies that the Signaling server must support a communication protocol between the two applications.

Although not described, load balancing by means of additional IPTV Application Servers can be accomplished by redirecting clients upon the initial signaling. But this requires additional components at the network level for service virtualization.

The IPTV AS prototype architecture was specifically tailored for live streaming. For VoD content streaming and multiple network characteristics, the real-time encoding of the Per-client stream is not scalable. An alternative would be the use of Scalable Video Coding (SVC) [20].

IV. Performance Evaluation

The goals while testing the prototype system were to evaluate the overall scalability of the solution as well as the functionalities it provides.

The IPTV AS prototype and media content server were deployed on separate machines running Intel Core2Duo at 2.4GHz with 2GB of RAM.

The IPTV Clients were deployed on a series of laptop computers ranging from Intel Centrino 1.7 GHz to Intel-Core2Duo 2.4GHz and from 1GB up to 2Gb of RAM.

A campus High-Speed LAN and a wireless CDMA2000 network were used throughout the tests.

The encoder was set up with 10 different quality levels for each stream, ranging from 16kbps to 292kbps.

The functionalities under test included:

- session establishment and tear-down;
- *Trick Functions* (e.g., play, pause);
- dynamic QoS/QoE parameter adaptation for both Per-client and General Purpose streams.

The IPTV AS scalability was evaluated measuring CPU load and memory usage.

The codecs used were the MPEG-4 Visual (Part 2) and MPEG-4 Advanced Visual Codec (H.264).

The results on the LAN were nearly within the limits specified by the Broadband Forum for IPTV services. It was verified that the system adapts well to higher quality levels due to the low congestion and available bandwidth.

Table I
SIGNALING OF APPLICATION - IN A LAN.

	SS (s)	ST (s)	CC (s)	QC (s)	PT (s)
Average	2.94	0.64	2.51	1.52	0.29
Deviation	0.49	0.39	0.48	0.41	0.16
Maximum	4.00	1.70	3.20	2.00	0.60
Minimum	2.22	0.20	2.00	0.90	0.10
TR-126 Limits [21]	2.00		2.00		0.20

SS-Session Startup; ST-Session Tear-down; CC-Channel Change; QC-Quality Change; PT-Pause Time

The results on the CDMA2000 network were very satisfactory considering the characteristics of the radio link, due to the spiky nature of the CDMA2000 RLP (Radio Link Protocol) processing.

Table II
SIGNALING OF APPLICATION - IN A CDMA2000 NETWORK.

	SS (s)	ST (s)	CC (s)	QC (s)	PT (s)
Average	3.74	1.06	3.79	3.43	0.36
Deviation	0.77	0.82	0.71	0.77	0.21
Maximum	6.00	3.00	5.60	5.00	0.70
Minimum	3.10	0.40	3.00	2.10	0.10
TR-126 Limits [21]	2.00		2.00		0.20

SS-Session Startup; ST-Session Tear-down; CC-Channel Change; QC-Quality Change; PT-Pause Time

These values could be reduced with the IPTV AS prototype relocation to the CDMA2000 core. The behavior of the system shows clearly that quality levels are dynamically adapted to low bandwidth and high latencies and losses.

Although the channel availability values are higher than the aforementioned limit, the solution provides a reasonable QoE for users with seamless channel changes and quality adaptation.

The system scalability was tested for both Per-client and General Purpose streams. As expected, the General Purpose stream offers higher scalability, as it shares resources among the connected clients.

This approach successfully served up to 70 clients with just one IPTV AS.

Under the same test conditions the Per-client stream served only 10 clients until reaching a maximum on the CPU load using the MPEG-4 Visual codec.

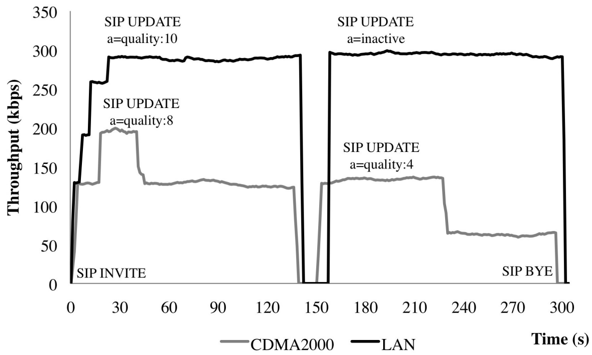

Figure 8. Dynamic Quality level adaptation to network conditions

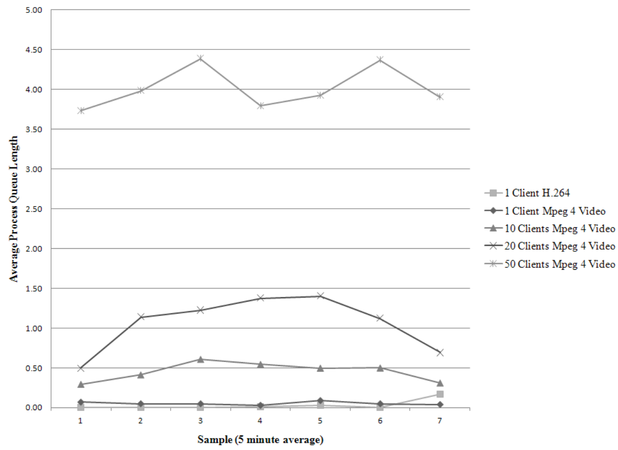

Figure 9. CPU Load of the IPTV AS in General Purpose streams

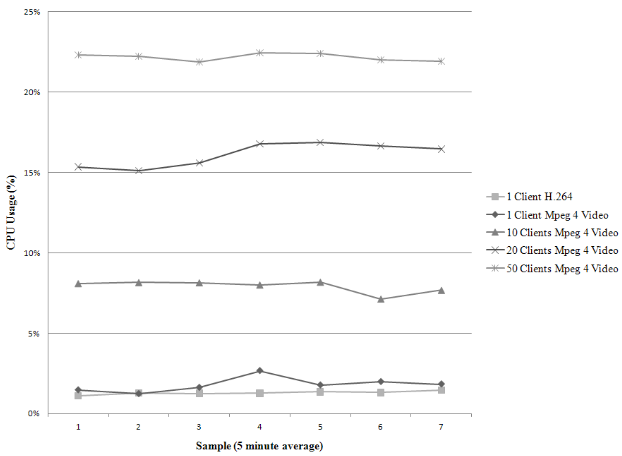

Figure 10. Scalability of the IPTV AS in General Purpose streams

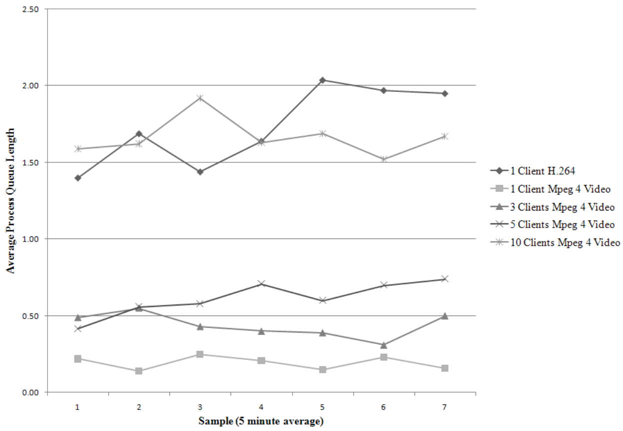

Figure 11. CPU Load of the IPTV AS in Per-client streams

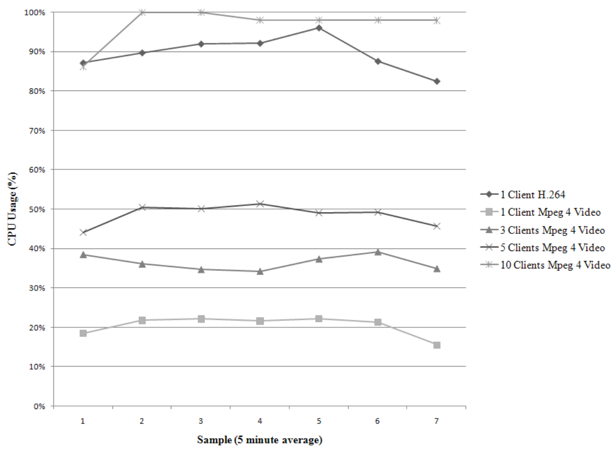

Figure 12. Scalability of the IPTV AS in Per-client streams

V. Conclusion

This paper describes the development, implementation and evaluation of a SIP based IPTV architecture realized within the scope of the european project *My eDirector 2012* [11] and respecting the requirements specified by a portuguese 3G CDMA2000 mobile network operator.

The tests have proved that the overall performance of the system can successfully adapt and scale to a large number of clients with distinct network conditions, always offering the highest possible QoE to the user, turning the proposed architecture suitable for live multimedia streaming.

The implemented QoS adaptation method allows dynamic updates of session parameters, maximizing the QoE and turning the solution suitable for live multimedia streaming, independently of the cast mode (unicast or multicast).This means, on the server side, that the number of different quality streams at any moment in time is also independent of the cast mode.

Future work will cope with further service developments, essentially related to Media Delivery Functions like adaptive content processing, enhancements to channel switching delays and to dynamic adjustment of QoS/QoE parameters.

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