An Adaptive e-Learning Platform based on IP Multicast Technology

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Abstract

A wide range of applications involving different types of media, with distinct quality of service and network resources requirements have been fostering the computer communications community in order to improve the service provided by the Internet. Besides the IETF recent proposals for introducing QoS in the Internet, multicast technology proposed by S.Deering assumes a major role in supporting group-oriented applications.

This article describes the design, implementation and operation of an adaptive distance learning system based on IP multicast technology accessible through a Web browser. This system uses public domain multimedia multicast to build a system which adapts conveniently to the available network resources and to the hardware capabilities of the end-system.

The system architecture includes an adaptive module based on Java applets and embedded Javascript, responsible for assessing the existing operating conditions, by collecting the client's system performance (e-student's host) and relevant group characteristics. The collected data is subsequently computed weighting parameters, such as the available bandwidth at the client side, the round-trip time between the client and the remote server, the client's current CPU load and free memory. The obtained result is used for proper multicast applications scheduling and parameterisation in a transparent way
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***Keywords** - QoS adaptation, multicast, web-based e-learning*

1. Introduction

The Internet, mainly the new generation, has been standing as panacea for the demands of digital communication in several domains.

Education and particularly distance learning did not escape the "webization" process. With WWW service evolution, new distributed multimedia conference applications were incorporated bringing improved interactivity and pro-human relations. Groupware applications are increasingly representative in the Internet home applications market, however, the Quality of Service (QoS) provided by the network is still a limitation [1], which impairs performance assurance. Such applications have found in multicast [2] technology an ally for their implementation and scalability. Multicast support is now mandatory in the design of new generation networks. Being an efficient method of group communication, multicast will boost future internetworking and applications development. Although multicast reduces network traffic, group dimension and Internet heterogeneity may originate scalability problems. In environments where the available resources suffer considerable random fluctuations, applications shall provide mechanisms to preserve the quality of the group communication critical parameters.

The application ability to adapt itself dynamically depending on the resource availability can be considered a quality factor [3]. Tolerant real-time applications, such as videoconferences, are candidates to benefit from this innovation. However, not all include adaptive technology able to provide both end-system and network quality-aware behaviour. Adaptation, in these cases, can be obtained by introducing a multi-platform middleware layer responsible for tutoring the applications' resources (adjudication or limitation) based on the available processing and networking capabilities [4].

2. Related Work

Currently, the e-learning research community tries to harmonise the proficuous application of the existing technology, conditioned by the evolution/social state of the humankind. Distance learning environments based on information technology and digital contents must be customised to answer this natural difference. Thus, the conception of new methodologies in education does not have to move away from personalization despite the virtual process [5].

Projects such as IRI (Interactive Remote Instruction) described in [6] have been precursors of distance collaborative learning based on telematic interaction with multimedia contents. Education, mainly at higher levels, can benefit from the encapsulation of telematic and multimedia means [7, 8, 9]. One of the rules to guarantee the success of conference applications in distance education is tightly closed to the simplification of their parameterisation.

The experiments carried out in [10], regarding an agent-based adaptation scheme supporting QoS guarantees, show the positive effects of bandwidth and CPU reservation applied to an architecture of adaptive video service.

In [11], a novel Middleware Control Framework to enhance the effectiveness of QoS adaptation decisions by dynamic control and reconfiguration of internal parameters and functionalities of a distributed multimedia application is presented. The objective is to satisfy both system-wide properties (such as fairness among concurrent applications) and application specific requirements (such as preserving the critical performance criteria). This framework evolved to Agilos (Agile QoS) [12], a Middleware Control Architecture, referred as a viable approach to control the adaptive behaviour of applications so that the best possible application-level QoS is achieved under any resource conditions during the lifetime of the applications.

In [13] is presented a project which integrates QoS adaptation focusing the telelearning specificity, proposing a QoS specification strategy and delivery criteria that best fit the specifications to the available resources, mainly by monitoring bandwidth. In order to provide QoS based delivery a prioritisation method has been designed to retrieve information according to the preferences of a user. Java applets and CGI programming tools are used to provide an interactive web retrieval environment.

3. Methodologies

This work involves the use of multicast technology and QoS preservation implementing adaptability by middleware tutoring on end-system's distributed multimedia applications. Additionally, it follows the state of the art in terms of distance learning based on WWW services. Figure 1 shows this work context and its multidisciplinary nature.
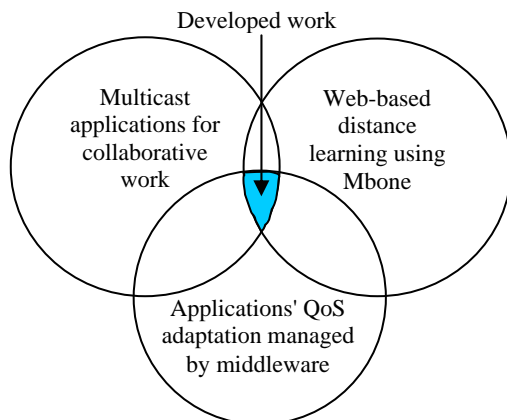

Figure 1 - Work context.

The system's architecture includes an adaptive module (sensor), based on Java applets and HTML forms managed by embedded Javascript code. The former is responsible for assessing the existing operating conditions, by collecting the client's system performance (e-student's host) and relevant group characteristics. The collected data is subsequently computed weighting parameters, such as the available bandwidth at the client side, the round-trip time between the client and the remote server, the client's current CPU load and free memory. The obtained result is used for adequate multicast applications scheduling and parameterisation in a transparent way, i.e. hiding configuration details from the user, usually not a computer expert. The parameters tuning consists of adjusting the video frame rate, bandwidth usage, image (e.g. chromatic richness) and audio quality.

Our focus is on the concept of "interactive e-learning services", relegating the concept of "e-learning course" to a secondary goal, which will be considered in future work.

The multicast tools used in this work are public domain software largely used for conference purposes in major universities and commercial institutions. Such applications are incapable of adapt their performance to resource availability variations. The solution to provide adaptability to applications assumes as mandatory the independence between application and platform. The session (or the real-time multimedia applications composing it) is launched, for each new active multicast group member, in a pre-parameterised and transparent manner.

4. Integrated Multicast Applications

Mbone sessions usually involve some multicast applications, which basically are:

- *rat* (*robust audio tool*) [14];
- *vic* (*videoconferencing tool*) [15];
- *wb* (*multiparty whiteboard*);
- *nte* (*network text editor*).

These popular applications appeared in the mid-nineties, developed at UCL and Berkeley Labs. In 1998, JMF [16] - Java Media Framework developed by Sun MicroSystems, has contributed significantly to multimedia distribution enhancement over the Internet. Although JMF's JMStudio does not allow command line pre-parameterisation, we used it at server side, as well the JMF plug-ins to deal with RTP objects in web pages (for video and audio reception only).

Considering application specificity and generated traffic, adaptability is only applied to interactive audio (*rat*) and video (*vic*) applications and services.

Applications' QoS parameters modulation policy emerged from experimental results and scientific references in this matter. For instance, videoconference

users, typically require better audio quality than video quality [17]. Videoconference communication success depends equally on factors such as frames per second received, image quality, resolution, size and illumination [18, 19, 20].

Vic and *rat* accept pre-parameterisation through command line options. The basic *rat* synopses is:

```
rat [options] addr/port
```

Rat parameters can be numerous (see http://www-mice.cs.ucl.ac.uk/multimedia/software/rat/documents/rat-man.txt), however, the only one to adapt this application is audio encoding, so that it is possible to set the format for data transmitted to the network. The different types of encoding use different amount of bandwidth. The parameter syntax

```
-f c1/c2/../cn
```

specifies the encodings used when transmitting audio, i.e. the primary encoding, secondary encoding, etc. The values allowed are *l16*, *pcm*, *dvi*, *gsm*, *lpc*.

Videoconferencing tool (*vic*) can also be pre-parameterised using the options available in the following syntax:

```
vic [ -A proto ] [ -B kbps ] [ -C
conference ] [ -c dither ] [ -D device ]
[ -d display ] [ -f format ] [ -F fps ] [
-H ] [ -I channel ] [ -K key ] [ -M
colormapFile ] [ -m mtu ] [ -N
sessionname ] [ -o clipfile ] [ -P ] [ -s
] [ -t ttl ] [ -U interval ] [ -u script
] [ -V visual ] [ -X resource=value ]
dest/port[:rport][/format/ttl/nchan,dest2
/port2[:rport2]/format2/...]
```

For this work, the representative parameters are:

-B <u>Kbps</u>   Set the maximum value of the bandwidth slider to <u>Kbps</u>.

-c <u>dither</u>   On a color-mapped display, use the algorithm indicated by <u>dither</u> to convert to the available color palette. <u>dither</u> may be one of the following: *ed*, *gray*, *od*, *quantize*.

-f <u>format</u>   Indicates video encoding format: h261, h263, jpeg, nv, ...

-F <u>fps</u>   Set the maximum value of the frame rate.

5.   Developed Work

Application's adaptability is performed resorting to a middleware layer. Several modules (java applets and embedded javascript in HTML forms) are responsible for monitoring resource availability conditions present in end-system environment, i.e. processing (CPU and memory) and network (bandwidth and delay) capabilities. Subsequently, other architecture module will compute collected data to transmit adaptation parameters in command line options to proactively launch applications.

The system architecture is presented in Figure 2, where the middleware layer is nuclear to assure QoS conditions in e-learning process.
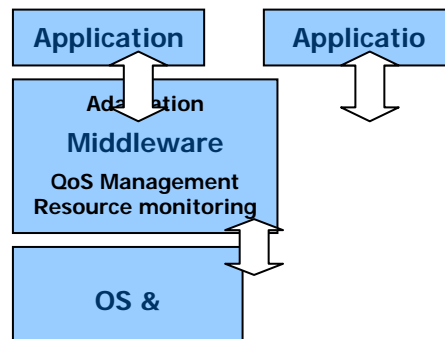

Figure 2 - System's architecture.

To achieve QoS-aware behaviour from the system it was necessary to:
- evaluate and adjust user and application's QoS profile needs facing available QoS conditions;
- adjust frame rate and image quality according to the available bandwidth, when transmitting video;
- use more compact encoding formats for audio and video to preserve resources for critical parameters and limit bandwidth adjudication, particularly in a resource scarce scenery;
- provide (transparently) to the user the best possible tools' configuration co-ordinating QoS needs, available resources and the e-learning services specificity.

The inputs used in the adaptation module are the available bandwidth and network round trip time (rtt) measured using a moving average of several trials. Additionally, the processing status input considers the processor load and free memory.

5.1 Distance Learning System Features

The distance learning system presents a wide range of features to provide distinct service levels such as:
- virtual academy, based on web interface with refined usability, integrating services for the e-learning community;
- registration, authentication and maintenance of educational agents data;
- multicast sessions maintenance and scheduling;
- access to asynchronous material, e.g. VoD, slide presentations an other multimedia documents;
- interactive Multimedia Multicast Conferences (MMCs) with QoS adaptation to clients and other multicast tools for shared workspace;
- provision of discussion tools, e.g. forum and chat.

The e-learning system is accessible at URL: http://www.esa.ipb.pt/multicast. The corresponding web interface illustration is shown in Figure 3.
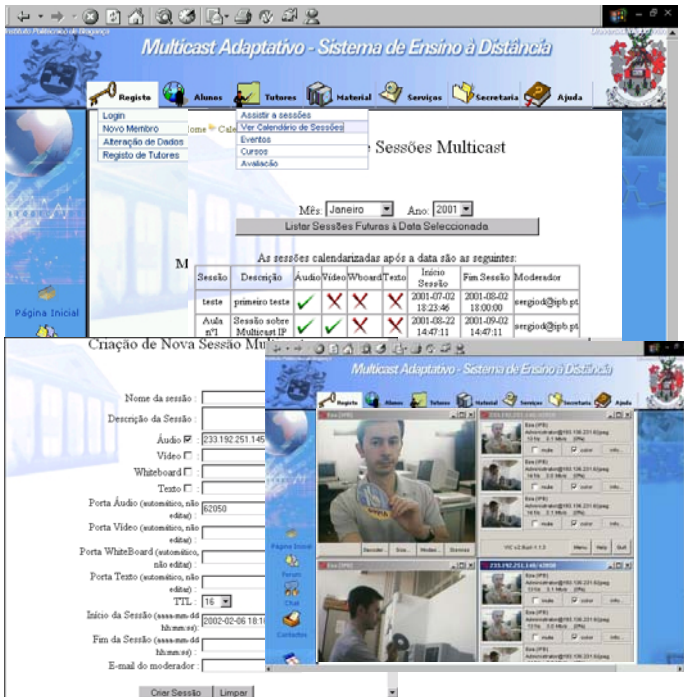

Figure 3 - E-learning system's web interface snapshots.

5.2 Adaptability Computation

The values for the parameters allowing to adjust the applications' behaviour derive from a mathematical expression that generates the QoS adaptation mode. Each mode indexes the respective set of adjustments, which the application will receive by pre-parameterisation. Since QoS scale varies from mode 1 to 5, when the obtained result is under or over this range it will be assigned to the nearest limit.

This is the formula to obtain the adaptation mode:

$$M = (int) \ (\ B/(RTT/2) + FM/P) \ *K \qquad (1)$$

where,
M = QoS adaptation Mode (Table 1);
B = Bandwidth (Kbps); RTT = Round-Trip Time (ms);
FM = Free Memory (MB); P = Processor occupation (%);
K = 1/50 - constant to adjust the result to the (1 to 5) scale.

MODE	MAXIM BANDWIDTH	FRAME RATE	VIDEO CODEC	COLOR	AUDIO CODEC
5	1 Mbps	30 fps	H.261	Yes	L16
4	512 Kbps	25 fps	H.261	Yes	PCM
3	256 Kbps	20 fps	H.261	Yes	DVI
2	128 Kbps	15 fps	H.263	Yes	GSM
1	64 Kbps	10 fps	H.263	No	LPC

Table 1 - Set of parameters for QoS adaptation modes.

5.3 Adaptive System Evaluation

The prototype e-learning system under test showed good performance indicators, which validates the architecture model. Because video traffic is quantitatively more representative it was analysed preferentially. In Figures 4 and 5 is possible to assess the resource consumption for each QoS mode considered. Tests occur in different scenarios as regards image quality and scene movements.
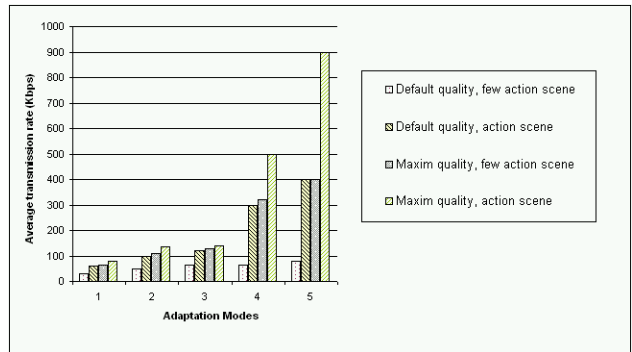

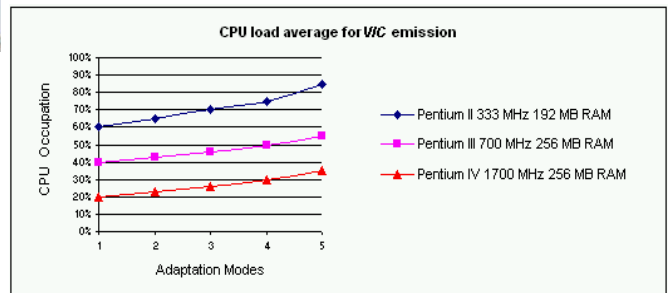Figure 4 - Bandwidth needs for each QoS mode.

Figure 5 - CPU occupation for each QoS mode.

QoS adaptation, when treated systematically in tolerant real-time applications, denotes advantages in group scalability and QoS sustainability in heterogeneous and unpredictable environments such as the Internet and certainly Mbone. Figures 6, 7 and 8 reveal a comparison between two sessions simulations, the first without QoS adaptation and the other including adaptation provided by the developed middleware layer. The results show that scalability is increased, but equally important is the fact that applications could benefit from an increase in resource availability what does not occur when using the default configuration. When resources availability decreases, then the system allocates them to critical parameters, for instance the frame rate should not go under 10 fps, while image quality can be poor or B&W as long as the contents are correctly perceived.

Limiting bandwidth to applications, not only with explicit parameterisation but mainly by choosing the right encoding format for e-learning sessions allows proficuous resource utilisation and proactive usability, avoiding network overload and congestion. If network load stays high is easier to recover if adaptation is used.

Adaptation also leads to a better probability to achieve a stable e-learning session with adequate QoS.
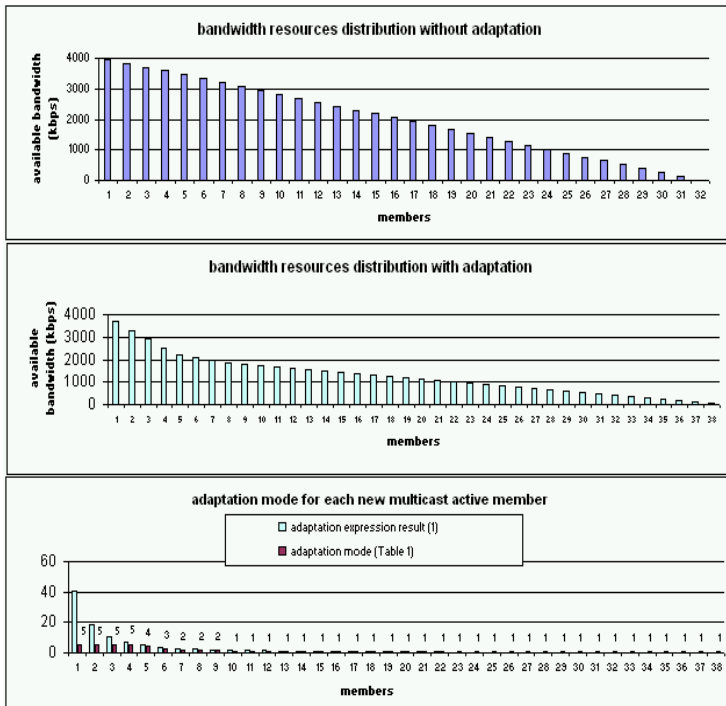
Figures 6, 7 and 8 - Sub-network multicast session simulations: comparison using the default settings (6) providing middleware adaptation (7) using QoS pre-parameterisation with different adaptation modes (8), when the multicast group size increases.

6. Conclusions

This work aimed to integrate a set of technological solutions in telematic and multimediatic research areas to achieve an adaptive e-learning system based on WWW services, adopting "ecological" practices in the Internet.

The system uses public domain multicast applications over Mbone network adapting its QoS parameters to preserve quality of critical parameters in e-learning session's specificity.

Middleware adaptation [11, 12] is a recent solution that appears to suit the present state of Internet and the requirements of new multimedia distributed applications. We use a middleware layer to manage QoS adaptation in interactive audio and video applications co-ordinating resource needs, their monitoring and adjudication. Significant results were obtained as regards group scalability, QoS sustainability and proactive resource utilisation.

Future developments include transparent resource reservation with RSVP combined with adaptive quality-aware behaviour of real-time tolerant applications and a framework for secure multicast sessions.

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