Estimation of Perceived Quality in Convergent Services

Pedro de la Cruz Ramos[1], Mario Cao Cueto[1], Raquel Pérez Leal[2], Francisco González Vidal[1]

[1]Depto. de Ingeniería Telemática
Universidad Politécnica de Madrid
Madrid, Spain
{pcruzr, mcao, vidal}@dit.upm.es

[2]Depto. de Teoría de la Señal y Comunicaciones
Universidad Carlos III de Madrid
Madrid, Spain
rpleal@tsc.uc3m.es

***Abstract*— Triple-Play (3P) and Quadruple-Play (4P) services are being widely offered by telecommunication services providers. Such services must be able to offer equal or higher quality levels than those obtained with traditional systems, especially for the most demanding services such as broadcast IPTV. This paper presents a matrix-based model, defined in terms of service components, user perceptions, agent capabilities, performance indicators and evaluation functions, which allows to estimate the overall quality of a set of convergent services, as perceived by the users, from a set of performance and/or Quality of Service (QoS) parameters of the convergent IP transport network.**

Keywords- Quality of Experience, Perceived Quality, Quality of Service, Network Performance, Quality Models.

I. INTRODUCTION

Customers of convergent Triple-Play (3P) and Quadruple-Play (4P) services expect a Quality of Experience (QoE) comparable to that obtained with traditional broadcast systems. Consequently, it is of utmost importance for 3P and 4P service providers to be able to measure, estimate and/or monitor user perceived quality in near real time, especially for the most demanding services such as broadcast IPTV.

User QoE in 3P/4P services depends on many factors, among other:

1) Perceived quality of each of the individual services, which in turn depends on:
   a) Perceived quality of each of the service components.
   b) Relationships, interactions and/or dependencies between the components.
2) Service availability and reliability.
3) System responsiveness, user-friendliness, etc.
4) Customer service.

For instance, 3P QoE depends on the perceived quality of the IPTV service, which in turn depends on audiovisual quality, which depends on audio quality, video quality and audio-video synchronization (lip sync), and so on.

This paper focuses on those elements of perceived quality that can be estimated, directly or indirectly, from performance or Quality of Service (QoS) parameters of the convergent IP transport network, i.e., parameters which can be measured at easily accessible reference points [1] or obtained from the Network Management System (NMS). These parameters include:

1) IP Packet Error Ratio (PER) and Packet Loss Ratio (PLR).
2) End-to-end IP packet delay.
3) Delay variation (jitter).

For instance, MPEG Video Quality can be estimated from QoS parameters such as PLR [2][3].

In order to estimate user perceived quality we propose the use of a matrix-based model, which allows to estimate the overall quality of a set of convergent services, as perceived by one or more types of users, from a set of performance and/or Quality of Service (QoS) parameters of the convergent IP transport network.

In the following sections the model is presented; its application to convergent services is described; the quality evaluation process is detailed; the main conclusions are summarized; and some future work is outlined.

II. PRESENTATION OF THE MODEL

The model is schematically depicted in Figure 1. Its elements are succinctly described in the following sections. It is thoroughly described in [4][5][6], where its application to a 3P (data + voice + video) service offering is also explained. The video service (VoD), however, is considered of little importance and thus dropped. In the case of domestic users, the voice service (VoIP) is also dropped, so that the global service reduces to a data service (Internet access + On-Line Gaming).

In this paper, instead, a full Triple-Play service offering, including data, voice and video services, is covered.

For the purposes of this paper, a "user" is anyone who "consumes" some service included in a 3P/4P service offering. Typically, they are unaware of the internal mechanisms used to provide the service, and of its composing elements. They are only interested in the "experience" delivered to them by these services, and judge the quality of this experience (QoE) by means of their subjective perceptions, and not by technical criteria.

Usually, we will not be interested in the individual QoE of specific users, but in the "average QoE" of a community or category of users with similar characteristics, i.e., of a "user type". Sometimes, we will even consider the average QoE of a wide sample of customers whith quite dissimilar characteristics, i.e., that of the "average user".

 ISBN: 978-1-61208-193-9

A. *Services and User Perceptions*

In Figure 1, the upper side of the matrix corresponds to the services and how the users experience those services as sets of user perceptions.

Services. For the purposes of this paper, a service is defined as a set of functionalities whose purpose is to satisfy certain needs and which are perceived as a whole by the users. We will distinguish between:

1) Overall or Global Services: they are offered by providers as a whole, but composed of more elementary services. An example is the 3P Service offered by a provider as a whole.
2) Final Services: components of Global Services. They are not offered independently by providers, but are perceived as independent services by users. Examples: Internet Access, IPTV, VoIP, etc.
3) Elementary or Basic Services: components of Final Services. They are not offered independently by providers. Users perceive them as separate, but not independent, services. Examples: Web Browsing, Electronic Mail, File Transfer, etc.
4) Support Services: they support the Final and/or Basic Services. They are not offered independently, and users are often unaware of their existence. Examples: ADSL access, DNS, DHCP, etc.

In this paper, "Service" will mean "Final Service" unless otherwise stated.

User Perceptions. A user perception is a factor that influences the evaluation of the service quality as perceived by users, i.e., the Quality of Experience (QoE).

It may be quantified by means of a valuation, similar to that obtained by subjective methods such as MOS, DSCQM, SSCQE, etc. [7][8]. In this paper, user perceptions will be quantified using the Standard MOS Scale (from 1=unacceptable to 5=excellent) [9].

For each user perception, **Global Valuation Factors (GVF)** should be defined as objective, quantifiable parameters which determine (or at least influence) the subjective perception of quality. They are the result of the performance achieved by providers and obtained by the users of the service. They provide a clean separation between technical performance parameters and user quality evaluations. For example a GVF for the perception of "Download Speed" may be the "Page Download Time".

B. *Agents and Agent Capabilities*

In the left side of Figure 1, the agents and their capabilities are depicted.

Agents. An agent is any component of a system which has individual, separate existence and provides an identifiable set of functionalities with the purpose of providing some service to the users. Examples: Content providers, Carriers, Access providers.

Agent Capabilities. These are the different functionalities provided by the agents, contributing to the provision of a service to the users. Examples: Connectivity, processing, data storage, data transfer.

For each agent there are **(Internal) Performance Parameters**, which are internal elements or factors that an agent may control or manage and that contribute to the performance of a capability. Typically, they are magnitudes related to the internal infrastructure or operation of the agent. Some typical examples are: throughput, bit error rate, MTBF.

C. *Matching Points and Performance Indicators*

As previously mentioned, the matrix-oriented quality estimation model tries to identify the dependencies between services and the performance and/or quality parameters related to the agents and their capabilities.

Matching Points. They represent the relationships or dependencies between user perceptions and agent capabilities, such that the capability affects or influences the perception. For instance, the data transfer capability of the transport network influences the loading speed perception in the web browsing service.

Performance Indicators. These are measurable magnitudes, associated to matching points, whose values determine or affect the user valuation of the corresponding perception. We will distinguish between:

1) Elementary Performance Indicators, which model the contribution of a single capability of an agent to a perception.
2) Local Performace Indicators, which model the contribution of all capabilities of an agent to a perception.
3) Global Performance Indicators, which model the contribution of all agents to a perception.

Some examples are: bandwith, delay, jitter.

D. *Quality Evaluation Process*

The Quality Evaluation Process comprises a set of sub-processes and functions. Figure 2 shows the information flow of these evaluation functions and processes, where the output of each step is the input to the next one. We will distinguish the following evaluation functions:

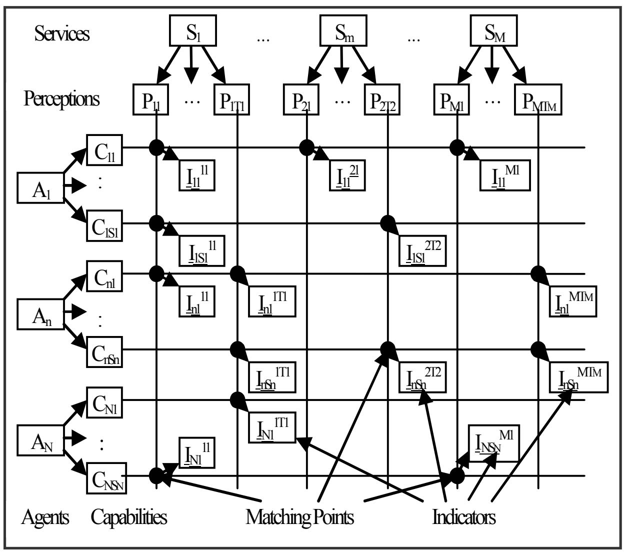

Figure 1. Matrix-oriented quality estimation model.

1) Performance Functions: compute the Elementary Performance Indicators from the Internal Performance Parameters.
2) Local Weighting Processes: compute the Local Performance Indicators from the Elementary Performance Indicators.
3) Global Aggregation Process: computes the Global Performance Indicators from the Local Performance Indicators.
4) Parameterization Functions: compute the Global Valuation Factors from the Global Performance Indicators.
5) Valuation Functions: compute the valuations of perceptions from the Global Valuation Factors.
6) Global Evaluation Process: computes the evaluations of the perceived quality of each Final Service and the overall evaluation of the Global Service, for each User Type and/or for the Average User. For this purpose, the Analytic Hierarchy Process (AHP) method [10] is used.

III. Application of the Model to Convergent (3P) Services

We will follow the application methodology described in [4]. We will try to estimate the average QoE of so-called “Residential Users”, i.e., domestic (home), non-enterprise users, whose interests are mainly the leisure and pastime opportunities given by broadcast IPTV, and the information access possibilities offered by Internet Access, and specifically, Web Browsing. These users also seek cost saving opportunities offered by VoIP.

For broadcast IPTV, these customers expect a QoE comparable to that of traditional broadcast systems (i.e., terrestrial or satellite TV). For VoIP, they will also expect a quality similar to that of POTS, but will very likely accept a quality similar to that of mobile telephony, if the cost savings are substantial.

Non-residential users, i.e., enterprise and SOHO (Small Office/Home Office), are usually not interested in TV services, and so in 3P services, and are thus not considered in this model.

A. *Identification of Components*

Following the model presentation described above, this section aims to identify the model components and define its corresponding parameters.

For the purposes of this paper, we will consider a 3P Global Service offering composed of the following **Final Services**:

1) Internet Access, including Web Browsing, Electronic Mail, File Transfer and File Sharing (P2P).
2) IP Telephony: Voice Call.
3) IPTV: Digital Video Broadcast (DVB).

As we are specifically interested in the estimation of user perceived quality from performance and/or QoS parameters of the underlying convergent IP transport network, we will deliberately ignore the Customer Service, Pricing and Marketing aspects of these services, as they cannot be estimated from network parameters, and will concentrate only in the technical quality aspects.

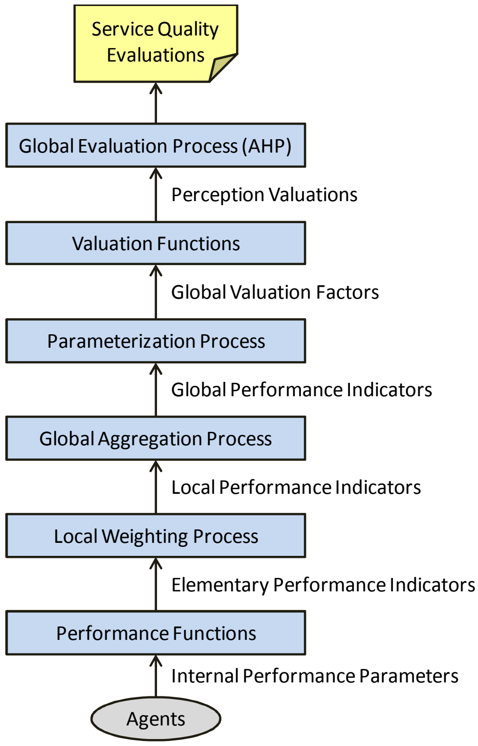

Figure 2. Matrix-oriented quality estimation model.

The **User Perceptions** that we consider relevant for each service are shown in Table I. Some perceptions are common to all services. The **Global Valuation Factors** for each user perception are also shown in Table I.

The **Global Performance Indicators** (GPI) for each user perception of a representative service (Digital Video

TABLE I. User Perceptions and Global Valuation Factors

Service	Perception	GVF
Web Browsing	Download Speed	Page Download Time
Electronic Mail	Response Speed	Response Time
File Transfer	Download Speed	Download Rate
	Upload Speed	Upload Rate
File Sharing	Download Speed	Download Rate
Voice Call	Voice Quality	R-Factor Codec Parameters
	Response Speed	Response Delay
	Call Setup Speed	Call Setup Delay
Digital Video Broadcast	Video Quality	Video Quality Metric
	Audio Quality	PEAQ Metric
	Lip Sync	Audio-Video Delay
	Channel Change Speed	Channel Change Time
All Services	Availability	Successful Connection Percentage
	Reliability	Interrupted Connection Percentage

Broadcast) are shown in Table II. The detailed relationships between indicators and GVFs (parameterization functions), and the process for deriving Global Performance Indicators (GPI) from Local and Elementary Performance Indicators (LPI/EPI) (i.e., the Local/Global Weighting Processes) will be given in Section IV.

For the identification of **Agents** we will use the network model and reference points recommended in [1]. The main agents are:

1) Content Provider(s), which are the ultimate responsibles of the delivery of the final services.
2) Service Provider(s), that we further subdivide into:
   a) Internet Service Provider (ISP), which provides Internet Access Services to end users. It may also integrate some additional services.
   b) Network Services Provider (NSP), which provides some of the Support Services (such as DNS, DHCP, etc.).
   c) Service Centers, which host the Final Services and provide connectivity between the ISPs and the Content Providers.
3) Network Provider(s), that we further subdivide into:
   a) Access Network Provider, which transports the information between the end-user and the ISP.
   b) Core (Transport) Network Provider (Carrier), which includes all those elements which connect the ISP that hosts the final service to other ISPs, e.g., neutral points, international accesses, inter-ISP accesses, etc.
4) End-User, including the User Plattform and Customer Premises Equipment (CPE).

The most relevant capabilities for each agent are shown in Table III.

TABLE II. GLOBAL PERFORMANCE INDICATORS (GPI) FOR A REPRESENTATIVE SERVICE (DIGITAL VIDEO BROADCAST)

Perception	Indicators
Video Quality	Packet Loss Ratio Video Coding Rate Image Size (Resolution) Image Rate Codec Parameters
Audio Quality	Packet Loss Ratio Audio Coding Rate Codec Parameters
Lip Sync	Audio-Video Delay
Channel Change Speed	IGMP Leave Time IGMP Join Time Key Acquisition Time Program Decoding Time Key-Frame Acquisition Time Frame Reordering Time Error Correction Time Processing Time Buffering Delay

B. Definition of Matching Points.

The relationships (Matching Points) between User Perceptions and Agent Capabilities depend on the precise information flows. We may distinguish four cases, depending on whether the content server is internal or external to the ISP, and whether or not the content is "cached" (stored) in the ISP or in the user platform.

For the purposes of this paper, we will consider the case where the content server is external to the ISP and there is no content caching outside the content provider. The resulting matching points between capabilities and perceptions are shown in Table III.

IV. QUALITY EVALUATION PROCESS

In this section, we will describe in detail:

1) The local and global weighting and/or aggregation processes (including weighting matrixes and/or metrics), valuation functions and quality models for each service.
2) The process for computing the Global Perceived Quality from the valuations of the perceptions for each service.

TABLE III. PERCEPTION-CAPABILITY MATCHING POINTS.

	Services	Web Browsing	Electronic Mail	File Transfer		File Sharing	Voice Call	Digital Video Broadcast				All Services	
	Perceptions	Download Speed	Response Speed	Download Speed	Upload Speed	Download Speed	Voice Quality	Video Quality	Audio Quality	Lip Sync	Channel Change Speed	Availability	Reliability
Agents	Capabilities	Matching Points											
User Platform	Processing	X	X	X	X	X	X	X	X	X	X	X	X
	Transfer	X	X	X	X	X	X	X	X	X	X	X	X
CPE	Processing	X	X	X	X	X	X	X	X	X	X	X	X
	Transfer	X	X	X	X	X	X	X	X	X	X	X	X
Access Network	Upstream C.		X		X		X				X	X	X
	Downstr. C.	X	X	X		X	X	X	X	X	X	X	X
Transport Network	Upstream C.		X		X		X				X	X	X
	Downstr. C.	X	X	X		X	X	X	X	X	X	X	X
ISP	Internal C.	X	X	X	X	X	X	X	X	X	X	X	X
	External C.	X	X	X	X	X	X	X	X	X	X	X	X
NSP	Connectivity	X	X	X	X	X					X	X	X
	Processing	X	X	X	X	X					X	X	X
Service Centers	Upstream C.		X		X		X				X	X	X
	Downstr. C.	X	X	X		X	X	X	X	X	X	X	X
	Processing	X	X	X	X	X	X	X	X	X	X	X	X
Content Provider	Upstream C.		X		X		X				X	X	X
	Downstr. C.	X	X	X		X	X	X	X	X	X	X	X
	Processing	X	X	X	X	X	X	X	X	X	X	X	X

A. Performance Functions

The Performance Indicators corresponding to the capabilities of each agent will be measured directly (or obtained from the Network Management System). Thus Performance Functions are not required in this case.

In the most general case, where Performance Indicators cannot be measured directly, they should be derived from Internal Performance Parameters measured for each agent (or obtained from the NMS) by means of suitable Performance Functions.

B. Local Weighting Process

As we are considering the case of a single type of flow (see Section III.B), there is no need for a local weighting process: the contributions of the relevant capabilities of each agent are used directly in the global weighting process.

In the most general case, when several types of flows are considered, the contribution of each capability of each agent should be weighted depending on its participation in each flow and the importance or contribution of each flow to the total information flow.

C. Global Aggregation Process

For the Global Aggregation Process, simple metrics will be used as far as possible. They are summarized in Table IV.

D. Valuation and Parameterization Functions

As mentioned before, the valuation and parameterization functions relate the perceptions for each service to Global Valuation Factors and Global Performance Indicators.

In the next subsections, we provide models for the estimation of perceived quality for the main Basic Service of each Final Service.

1) IPTV: Digital Video Broadcast

We have developed our own model for estimating the video quality in IPTV. An early version of the model is described in [2], and a more advanced version in [3].

$$MOS = \begin{cases} 5 - 4\cdot VQM & VQM \le 1 \\ 1 & VQM > 1 \end{cases} \quad (1)$$

$$VQM = VQM_C + VQM_L \quad (2)$$

$$VQM_C = VQM_{REF} \cdot (VCR/VCR_{REF})^{-K_C} \quad (3)$$

$$VQM_L = (1-VQM_C) \cdot (PLR/PLR_1)^{K_L} \quad (4)$$

where

VQM	is the Video Quality Metric as specified in [11]
VQM_C	is the contribution of coding to VQM
VQM_L	is the contribution of packet losses to VQM
VCR_{REF}	is a reference VCR (e.g., 1Mbps)
VQM_{REF}	is the value of VQM at the reference VCR
PLR_1	is the value of PLR for which VQM = 1

VQM_{REF}, K_C, PLR_1 and K_L depend on the codec, the coding parameters, and the characteristics of the video sequence (type, format, spatial and temporal complexity, information contents, etc.).

TABLE IV. METRICS FOR THE GLOBAL AGGREGATION PROCESS

Indicator	Metric
Delay	Additive
Delay Variance	Additive
Jitter	Rooted Sum of Squares (RSS)
Bandwidth	Concave
Packet Passthrough Ratio	Multiplicative
Packet Loss Ratio	Additive

PLR_1 and K_L also depend on VCR. We have found that their variation with VCR fits very well to a function of the form:

$$F(VCR) = A + B\cdot VCR\cdot(1+C\cdot e^{-(VCR/D)^K}) \quad (5)$$

In order to estimate the Audiovisual Quality for synchronized audio and video streams, we use the model described in [12][13]:

$$Q_{AV} = K_0 + K_A\cdot Q_A + K_V\cdot Q_V + K_{AV}\cdot Q_A\cdot Q_V \quad (6)$$

where

Q_{AV}	is the Audiovisual Quality Factor
Q_A	is the Audio Quality Factor
Q_V	is the Video Quality Factor

Q_{AV} must be converted to the standard MOS scale using the E-Model conversion function specified in [14]:

$$MOS = \begin{cases} 1 & Q_{AV} < 0 \\ 1+0{,}035\cdot Q_{AV}+Q_{AV}\cdot(Q_{AV}-60)\cdot(100-Q_{AV})\cdot 7\cdot 10^{-6} & 0\le Q_{AV}\le 100 \\ 4{,}5 & Q_{AV} > 100 \end{cases} \quad (7)$$

Q_V is derived from the MOS value given by (1) using the E-Model inverse function specified in ITU-T G.107 [14].

There are other factors that contribute to the global quality perception of the IPTV service, such as audio quality, audio-video synchronization (lip sync), channel change time, etc. In order to compute the global quality perception all these factors must be taken into account.

The Perceived Global Quality of the IPTV service will be computed using a nonlinear model:

$$Q_{IPTV} = K_{IPTV}+K_{AV}\cdot Q_{AV}+K_{Tav}\cdot Q_{Tav}+K_{Tcc}\cdot Q_{Tcc} + K_{AVTav}\cdot Q_{AV}\cdot Q_{Tav}+K_{AVTcc}\cdot Q_{AV}\cdot Q_{Tcc}+K_{TavTcc}\cdot Q_{Tav}\cdot Q_{Tcc} \quad (8)$$

where

Q_{IPTV}	is the Global Quality of the IPTV service
Q_{AV}	is the Audiovisual Quality given by (7)
Q_{Tav}	is the Perceived Quality due to audio-video desynchronization (lip sync)
Q_{Tcc}	is the Perceived Quality due to Channel Change Time (CCT)
$Q_i\cdot Q_j$	are the interaction terms

The coefficients K_i will be computed using the AHP method.

2) **IP Telephony: Voice Call**

In order to estimate the voice quality perception in IP Telephony, the adaptation of the E-Model [14] for VoIP given in [15] [16] will be used:

$$R = Ro - Is - Id - Ie + A \quad (9)$$

$$Id = \begin{cases} 0.024 \cdot d & d < 177.3 \\ 0.134 \cdot d - 19.503 & d \geq 177.3 \end{cases} \quad (10)$$

$$Ie = a \cdot \ln(1 + b \cdot \rho) + c \quad (11)$$

where

- R — is the R-Factor of the E-Model
- Ro = 93.2 — is the signal/noise ratio for 0dBr
- Is — is the degradation of the voice signal
- Id — is the degradation caused by delay and delay variation (jitter)
- Ie — is the degradation caused by the equipment (coding and packet loss)
- A — is the User Expectation Factor
- d — is the end-to-end delay in miliseconds
- ρ — is the end-to-end packet loss ratio
- a,b,c — are coefficients that depend on the codec

The R-Factor will be converted to the standard MOS scale using the E-Model conversion function [14]:

$$MOS = \begin{cases} 1 & R<0 \\ 1+0{,}035 \cdot R+R \cdot (R-60) \cdot (100-R) \cdot 7 \cdot 10^{-6} & 0 \leq R \leq 100 \\ 4{,}5 & R>100 \end{cases} \quad (12)$$

There are other factors that contribute to the global quality perception of the service, such as dial tone delay, call setup time, etc. In order to compute the global quality perception all these factors must be taken into account.

The Perceived Global Quality of the IP Telephony service will be computed using a nonlinear model similar to that used for the IPTV service (8).

3) **Internet Access: Web Browsing**

In order to estimate the preceived quality for Web Browsing in the Internet Access service, we will use the model proposed in [4], which in turn is based on that proposed in [17]:

$$MOS = \begin{cases} 5 & T < 2 \text{ seg} \\ 5 - \log_2 T/2 & 2 \text{ seg} \leq T \leq 30 \text{ seg} \\ 1 & T > 30 \text{ seg} \end{cases} \quad (13)$$

$$T = T_{DNS} + 2 \cdot RTD + T_{MAIN} + N \cdot S/B \quad (14)$$

where

- T — is the average page download time
- T_{DNS} — is the time needed for name resolution
- RTD — is the Round Trip Delay
- T_{MAIN} — is the main page download time
- N — is the average number of objects in a page
- S — is the average object size
- B — is the effective bandwith

The Perceived Global Quality of the Internet Access service will be computed by combining the Perceived Quality evaluations for each Basic Service using a linear model as proposed in [4]:

$$Q_{IA} = K_{WB} \cdot Q_{WB} + K_{EM} \cdot Q_{EM} + K_{FT} \cdot Q_{FT} + K_{FS} \cdot Q_{FS} \quad (15)$$

where

- Q_{IA} — is the Perceived Quality of the Internet Access Service
- Q_{WB} — Web Browsing Service
- Q_{EM} — Electronic Mail Service
- Q_{FT} — File Transfer (FTP) Service
- Q_{FS} — File Sharing (P2P) Service

The coefficients K_i will be computed using the AHP method [10].

E. Global Evaluation Process

In this section, the contributions of the different elements of the model are weighted and combined in order to produce a global evaluation of the perceived quality of the 3P service. The AHP method [10] will be used when the weights cannot be determined in a more specific way.

1) **Evaluation of Perceptions**

Once the different perceptions related to a service have been derived (valuation and parameterization functions), they must be combined in order to obtain the global evaluation of the service. For each service, an AHP matrix [10] should be used to define the relative importance of the different perceptions.

For all services, we have considered that service availability has extreme importance, and service reliability strong importance for the users, relatively to other perceptions. For other perceptions, we have considered the primary perceptions (other than service availability and reliability) as moderately more important than the secondary perceptions. These ratings will be refined once we had more evidence of the relative importance of these perceptions for domestic users.

2) **Evaluation of Services**

In [4], all services are evaluated in a single step. Instead, we have decomposed the Service Evaluation process in two steps: first, the relative importance of the Final Services is rated; then, the relative importance of the Elementary Services of each Final Service is rated. This method scales better to a situation with many Final Services, each in turn composed of many Elementary Services.

The relative weights for the Final Services are shown in Table V. They are derived from service usage data [18].

TABLE V. IMPORTANCE WEIGHTS FOR FINAL SERVICES.

Service	Internet Access	IP Telephony	IPTV
Home percent	63,9	80,6	99,6
Weight	0,2618	0,3302	0,4080

As an example, the relative importance (AHP Matrix) for the Elementary Services of the Internet Access Service is shown in Table VI. The value (rating) in each cell represents the importance of the service in the row relative to the service in the column. The precise meaning of each rating is described in [10], but intuitively a higher rating means that the row is more important relative to the column.

The importance ratings are derived from those in [4] after removing the unused services and including the new ones. We have given File Sharing the same importance as File Transfer, and kept the relative importance of other services.

The Consistency Ratio (CR) of this matrix is 2.25%<10%, so the relative importance factors are acceptably consistent. The corresponding weights are shown in Table VII.

V. CONCLUSION

A model for the estimation of quality as perceived by the users (i.e., the user Quality of Experience, QoE) in Triple-Play (3P) and Quadruple-Play (4P) services has been presented. The model is based on a matrix framework defined in terms of user types, service components, and user perceptions on the user side, and agents, agent capabilities, and performance indicators on the network side. A Global Quality Evaluation process, based on several layers of evaluation functions, has been described, that allows to estimate the overall quality of a set of convergent services, as perceived by the users, from a set of performance and/or Quality of Service (QoS) parameters of the convergent IP transport network. The model has been refined for the particular case of residential (domestic) users with a specific information flow where the content server is external to the ISP and there is no content caching outside the content provider. The full sets of services, user perceptions, valuation factors, agents and agent capabilities have been provided, as well as the full matrix of matching points between agent capabilities and user perceptions. Performance indicators, as well as valuation and parameterization functions for some representative services (Digital Video Broadcast in IPTV, Voice Call in IP Telephony, and Web Browsing in Internet Access) have been provided. For Global Service Quality evaluation, weights for the Final Services, derived from service usage statistics, have been provided, as well as an example of the use of the AHP method for deriving the weights of the Elementary Services of a Final Service (Internet Access). In summary, the paper shows the applicability of the proposed model to the estimation of perceived quality (Quality of Experience) in convergent 3P/4P services.

TABLE VI. AHP MATRIX FOR THE INTERNET ACCESS SERVICE (DOMESTIC USERS)

	Web Browsing	**E-Mail**	**File Transfer**	**File Sharing**
Web Browsing	1	4	6	6
E-Mail	1/4	1	3	3
File Transfer	1/6	1/3	1	1
File Sharing	1/6	1/3	1	1

TABLE VII. AHP WEIGHTS FOR THE INTERNET ACCESS SERVICE (DOMESTIC USERS)

Web Browsing	**E-Mail**	**File Transfer**	**File Sharing**
0.6121	0.2164	0.0858	0.0858

ACKNOWLEDGMENT

This research was partially supported by the Spanish Ministry of Science and Innovation grant TEC2008-06539 (ARCO Project).

REFERENCES

[1] ITU-T G.1081, “Performance monitoring points for IPTV,” International Telecommunication Union, October 2008.

[2] P. de la Cruz Ramos, F. González Vidal, and R. Pérez Leal, “Perceived video quality estimation from spatial and temporal information contents and network performance parameters in IPTV,” Proc. of the Fifth IARIA International Conference on Digital Telecommunications (ICDT 2010), pp. 128-131, Athens, Greece, June 2010.

[3] P. de la Cruz, R. Pérez Leal, and F. González Vidal, “A model for perceived video quality estimation from coding and QoS parameters in IPTV,” December 2011. Submitted to IEEE Communications Magazine: Special Issue on QoE Management in Emerging Multimedia Services.

[4] F. Liberal Malaína, “Proposal of a model and a methodology for quality management in telecommunication services,” PhD. Thesis, University of the Basque Country, Spain, September 2005.

[5] F. Liberal Malaína, A. Ferro, and J. O. Fajardo, “PQoS based model for assessing significance of providers statistically,” Proceedings of HETNET’05 Conference, 2005.

[6] F. Liberal Malaína, H. Koumaras, L. Sun, A. Ferro, A. Kourtis, and E. C. Ifeachor, “QoE in multi-service multi-agent networks,” International Journal of Communication Networks and Distributed Systems, 2006.

[7] ITU-R BT.500-12, “Methodology for the subjective assessment of the quality of television pictures,” International Telecommunication Union, September 2009.

[8] ITU-T P.911, “Subjective audiovisual quality assessment methods for multimedia applications,” International Telecommunication Union, December 1998.

[9] ITU-T P.800, “Methods for subjective determination of transmisión quality,” International Telecommunication Union, 1997.

[10] T. Saaty, “The Analytic Hierarchy Process,” McGraw Hill, New York, USA, 1990.

[11] ITU-T J.144, “Objective perceptual video quality measurement techniques for digital cable television in the presence of a full reference,” International Telecommunication Union, March 2004.

[12] M. N. Garcia and A. Raake, “Impairment-factor-based audio-visual quality model for IPTV,” International Workshop on Quality of Multimedia Experience (QoMEx) 2009, San Diego, California, USA, July 29-31, 2009.

[13] M. N. Garcia, R. Schleicher, and A. Raake, “Impairment-factor-based audiovisual quality model for IPTV: Influence of video resolution, degradation type, and content type,” EURASIP Journal on Image and Video Processing, Volume 2011, Article ID 629284, 2011.

[14] ITU-T G.107, “The E-Model, a computational model for use in transmission planning,” International Telecommunication Union, April 2009.

[15] L. Sun, "Speech quality prediction for voice over Internet Protocol networks," PhD. Thesis, University of Plymouth, U.K., 2004.

[16] L. Sun and E. Ifeachor, "New models for perceived voice quality prediction and their applications in playout buffer optimization for VoIP networks," Proceedings of IEEE International Conference on Communications (IEEE ICC 2004), Paris, France, pp. 1478-1483, 2004.

[17] R. D. van der Mei, "Performance analysis of communication networks," Faculty of Science, Vrije Universiteit, 2004.

[18] INE, "Encuesta sobre equipamiento y uso de tecnologías de la información y comunicación en los hogares 2011," Instituto Nacional de Estadística, Ministerio de Economía y Hacienda, Gobierno de España, October 2011.

 ISBN: 978-1-61208-193-9