Ecosystem for Customer Experience Assurance

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***Abstract*— Nowadays service providers focus all their effort on customers' satisfaction although determining the Quality of Experience (QoE) is not a trivial task. In addition, the evolution from traditional networks towards Next Generation Networks (NGN) is enabling service providers to deploy a wide range of multimedia services such as Internet Television (IPTV), Video on Demand (VoD), and multiplayer games services, all on the same underlying IP network. However, managing the satisfaction level of customers to provide a good user experience is not being an easy task due to the complexity of orchestrating network and customer data sources. This document proposes an ecosystem that allows managing customer experience in order to guarantee the quality levels delivered to end users, which is being implemented into the Celtic IPNQSIS project. The QoE ecosystem lies on a customer experience architecture formed by Data acquisition level, Monitoring level and Control Level. The work proposed in this paper will settle the basis of next generation Customer Experience Management systems.**

Keywords— Quality of Experience; Network Management; Customer Experience; Service Quality Management

I. INTRODUCTION

The multimedia landscape offered over the Internet of today is very rich and rapidly changing. New and attractive services may be created and spread quickly, with the help of social networks and recommendation mechanisms. It has become increasingly difficult to predict the future in the complex and rapidly changing multimedia ecosystem. The fast technological development has lead to new habits and new behavior in relation to end user media consumption. More media is consumed over the digital networks, and there is a large number of different terminals on which to consume the media.

This situation creates challenges for the operators and service providers, in delivering the service to the end users with acceptable quality. Users which are dissatisfied with the perceived quality are likely to switch to other service providers or operators. In the light of this development, it is obvious that monitoring and control of service quality is of increasing importance to avoid customer churn.

This challenge is dealt with in the Celtic IPNQSIS project, and this paper summarizes the Customer Experience Management (CEM) architecture proposed in the project in order to face the challenge posed. The CEM is implemented in the business case of IPTV, but it's usage can be extended to other services as well.

A paramount importance of the CEM is the Quality of Experience (QoE) component. This contains metrics that quantifies the customer satisfaction with the offered service. One reason for using QoE metrics instead of the traditional Quality of Service (QoS) is the fact the QoS does not correlate well enough with the actual user experience in the rich media landscape of today. The experience of a single user is naturally subjective, and hence impossible to predict, but it has been shown that the mean experience of a panel of users is a quite stable metric. This gives good hopes that QoE may be used for monitoring and control of user experience of e.g. TV services in operator networks.

The CEM is further described in section 2 of this paper. The individual components of the CEM are data sources, monitoring system and management system, all of which are described in section 3. The Celtic IPNQSIS project is further described in section 4.

II. MANAGING CUSTOMER EXPERIENCE

A. Customer Experience Management

The Customer Experience Management (CEM) approach is designed to focus on procedures and a methodology to satisfy the service quality needs of each end-user. Telecom operators are focusing on solutions to maximize the customer experience on audio and video services. CEM solutions essentially provide a service quality monitoring architecture to manage and optimize end-to-end customer experience. In 2009, TM Forum launched a working group called Managing Customer Experience (MCE) that constituted the major initiative to establish the links between e2e Service Quality and Customer Experience. The MCE program released three reference deliverables:

- TR 148 [4] examines the factors that influence customer experience and also a number of business scenarios for the delivery of digital media services, such as IPTV, Mobile TV, Enterprise IPVPN, and Blackberry, through a chain of co-operating providers;
- TR 149 [14] describes the customer experience/SQM (Service Quality Management) framework that has been designed to meet the need for assuring end-to-end (e2e) quality of customer experience when services are delivered using a chain of co-operating providers. It aims to support the business scenarios and requirements described in TR 148;

- TR 152 [15] captures at an executive level the main results of the Managing Customer Experience Focus Area Catalyst presented at Management World Orlando 2008.

CEM uses as main input the objective QoS parameters that contribute to QoE, i.e. NQoS (Network QoS indicators) and AQoS (Application QoS indicators). Combining both NQoS and AQoS we can calculate how the QoE is affected by encoding and transporting of multimedia services. Nonetheless, QoE is a subjective measure, so subjective assessment is the only reliable method. This means that CEM must also take into account customers' feedback. On the other hand, subjective testing is expensive, time consuming, and reference content is sometimes missing. Therefore, the CEM System (CEMS) solution should use the minimum available subjective tests on reference material by building prediction models for real-time estimation.

The first steps of the CEMS architecture developed in the context of IPNQSIS project focus on the construction of accurate as well as practical QoE prediction models. As a first step, we set out to measure and predict the user's QoE of multimedia streaming in order to optimize the provisioning of streaming services. This enables us to better understand how QoS parameters affect the service quality as it is actually perceived by the end-user. Over the last years, this goal has been pursued by means of subjective tests and through the analysis of the user's feedback. Our CEMS solution [12] proposes a novel approach for building accurate and adaptive QoE prediction models by using Machine Learning classification algorithms, trained on subjective test data. These models can be used for real-time prediction of QoE and can be efficiently integrated into online learning systems that can adapt the models according to changes in the network environment. Providing high accuracy of above 90%, the classification algorithms become an indispensable component of a multimedia QoE management system.

B. *Service Quality Management*

TM Forum TR 148 defines Service Quality Management (SQM) as the set of features displayed by an Operation Support System (OSS) that allow management of the quality of the different products and services offered by an enterprise. On the other hand, QoS is "[The] Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service." (ITU-T Rec. E.800 [16]). Therefore, the term quality of service is used in this document as a quality figure rather than referring to the ability to reserve resources.

SQM refers to the level of satisfaction a customer perceives when using a given service. To proactively manage this, e2e components that make up the service must be monitored and maintained. Typically, e2e service quality management requires a powerful data aggregation engine and a tool for e2e mapping of services. This way SQM systems make use of collected information (regarding user perceived QoS and the performance of the provision chain) in order to enhance the guarantee in the quality of the offered services. Customer traffic data is collected in order to formulate the characterization of services usage. By this way, these activities fulfill the generation of Key Performance and Quality Indicators (KPI/KQI), allow threshold management, SLAs surveillance, real-time monitoring, and are the most appropriate for the CEMS approach. The QoS perceived by the customer depends on: 1) the components that set up the service; 2) Business Processes related to the service; 3) the resources on which the processes are supported; 4) the performance of the underlying network. With the purpose of quantifying the perceived QoS, we must collect the KQI and KPI metrics for the services, and apply a methodology that correlates all the network factors.

III. QUALITY OF EXPERCIENCE ECOSYSTEM

Quality of Service or QoS is targeted towards measuring and controlling the network parameters. It has been recognized for some time that this is not enough. For example, if network congestion leads to packet loss, which one decoder may handle as a freezing in a video. A different decoder may show this as a short time distortion in part of the image. Although the measured packet loss is the same, the user experience is very different. Not only is it important to know what is actually presented to the user when an error occurs, it is essential to understand how it affects the human experience of it.

This understanding has led the definition of Quality of Experience, as a concept that also encompasses the experience of the user, when using a service [2]. The most accurate way of estimating QoE is by subjective testing, which could even be devised for live services. It may still not be sufficient. In a network that should be proactive i.e. react and adjust the QoE before its user gets annoyed and calls the support or even stop using the services, there are needs for objective metrics that can estimate the QoE for the different services in the network. Most likely there are different metrics for different services. Before these metrics could be applied and trusted they have be trained and evaluated using data collected from subjective tests. One may explore two different approaches in order to build QoE-related datasets and in-fine assess the impact of various parameters on the end-to-end QoE: (1) a controlled experiment with a number of volunteers asked to rate short videos, or (2) a crowd-sourced experiment to collect QoE data from a large number of volunteers, thus covering a wide range of situations.

When these metrics have come into place, the aim of IPNQSIS can be realized, that is optimizing the network performance guided by QoE measurements and estimations. This way, the effects of the control operations realized on the network will have a maximal impact on the actual service quality experienced by the users.

This section describes the design of the overall architecture to manage the customer experience. There are three separate levels (see Figure 1) that are described in the following subsections: Data Acquisition Level, Monitoring Level and Control Level, each one composed of different components. This reference architecture has been devised to define next generation CEMS, although not all components will be covered inside IPNQSIS scope.

This architecture is modular and open to easily add or remove components, system parameters and features.

1) Data acquisition level (QoE Data Sources): This level gathers the information of the different datasources: active and passive probes, and other probing devices technologies such as embedded agents or Deep Packet Inspectors.

2) Monitoring level (QoE Monitoring System): The input from the datasources is correlated, empowered and transformed to supervise both QoS and QoE. This level comprises all the components that transform basic indicators into customer experience metrics. On the other hand a set of generic GUI tools are also considered in this level.

3) Control level (QoE Management System): This level handles the QoE delivered to the customers and is fed back from the monitored level in order to act proactively into the network to improve customer satisfaction.

The following sections explain each of these levels.

A. QoE Data Sources

Probe systems are flattering increasingly popular as a tool to monitor real users Quality of Experience, being able to reproduce their behaviour in terms of automated tests carried out by active probes[3]. One of the main advantages of using these devices is that they provide greater versatility and flexibility than other systems based on mediation techniques, being able to be placed anywhere on the network, and even acting as real users do. Data provided by probes is usually highly detailed and offers an in-depth vision of the network behaviour and QoS experienced by customers. These systems allow measuring the quality in terms of customer satisfaction and optimizing service levels across the value chain.

There are active and passive probes. Active probes simulate end users behaviour, sending requests for services and analyzing the response, therefore providing and end-to-end view of the network. Passive probes capture traffic exchanged between service providers and end users, offering a view of the whole network at any protocol level. Combining the information obtained by both types of probes offers a new solution for monitoring services for Quality of Experience enhancement.

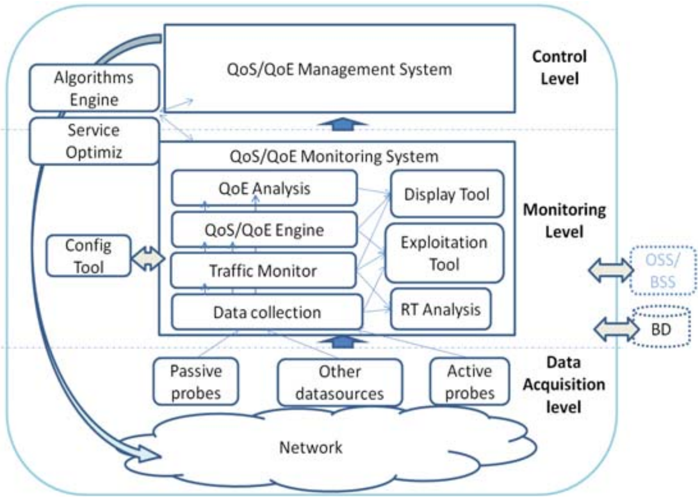

Fig. 1. IPNQSIS Architecture.

B. QoE Monitoring System

In this section the QoE monitoring element is described. It is composed of two components. The first one is the traffic monitor, which is transforming the information gathered by the data sources into monitoring data. The second one is the QoS/QoE engine, which converts monitoring data into quality figures.

- Traffic Monitor

There are some basic requirements that a netwok monitoring tool should fulfill in order to provide an accurate analysis of the traffic flow for QoS/QoE measurements [6]. One of them is to be able to capture packets at a very high rate from its underlying link without missing a significant portion of packets,.

IPNQSIS Customer Experience Management System (CEMS) will be based on the traffic monitoring and service supervision system [7], being all the required elementes designed and implemented within the project. IPNQSIS will make use of enhanced hardware and software probes that operate at different levels (from network core to end-users applications) in order to build the Monitoring Component, extracting the QoS measurement data for the captured flows.

IPNQSIS will make use of Deep Packet flow inspection tools on access networks in order to place a strong focus on IP traffic monitoring. The Monitoring Component will model traffic parameters related to content distribution, traffic trends and user characterization, for instance, content popularity (by time, location, access type, ect), traffic location, trafifc mix and traffic variation.

The Monitoring Component is composed of active probes, passive probes and traffic classification modules. Probes will be adapted to deal with multimedia services like IPTV, and QoE measurements will be defined and implemented. Deep Packet inspection methods and Bayesian Classifiers (which are based on the inherent features of the network traffic) will be used by the Traffic Classification Module. This module will provide means of detecting popular services for which QoE requirements will exist, feeding this relevant output to the Control Module.

- QoS / QoE engine

A vital part of a customer experience management system is the capability of assessing the quality experienced by the users of the monitored networks and services. As described in the previous sections, the system being developed in IPNQSIS project is capable of gathering low-level network quality measurement information from different kinds of network probes and using these to form network quality awareness at the monitoring level. This information, however, doesn't alone provide good insight on how the applications using the network area performing from the user's perspective. For this reason, another component, QoS/QoE engine, is added to map the network QoS data to QoE estimations. If the relationship between the QoS measurements and human perception is clearly understood [8] the information offered by QoS can be used to improve the decision criteria used in the network systems and to optimize the user's QoE [9].

QoE is a subjective measure of user's experience with the service being used. Its automatic realtime measurement is challenging by definition because the natural way of measuring it, asking the user's opinion, is difficult in practical scenarios. To mimic the experience of human subjects, different kinds of methods for mapping QoS parameters to QoE figures are being developed in IPNQSIS project. What is common for most of them is that some kind of a model (e.g. neural network, fuzzy system) for user experience is trained with controlled user tests in such a way that when the model is later used, it can give accurate enough estimations on user perceived quality just by observing objective quality parameters such as packet loss or jitter. It is important to note that the mapping between objective and subjective quality measures is application specific so no single model can be used to estimate the QoE for all applications, but instead the QoS/QoE engine has to run several QoE models on parallel and select the right one to be used based on the traffic flow being inspected. For certain applications where accurate offline objective metrics exist e.g. video, the training data could at least partly be generated without performing subjective test [21], which would greatly reduce the development time. Thus the capability of performing accurate traffic identification is also an important feature of the QoS/QoE engine in IPNQSIS CEMS.

C. QoE Management System

The ultimate reason for QoS measurement and QoE estimation in IPNQSIS customer experience management system is to be able to manage the QoE of network applications. For this reason, QoE management system is positioned on top of data acquisition and monitoring components. The system takes the QoE monitoring information and QoE/QoS models, along with policies and other constraints, as an input and performs network control actions as necessary. The goal for the control operations depends on the stakeholder in question. From a network operator's point of view the goal could be to optimize the use of network resources while maintaining acceptable level of quality, while a service provider might be interested in maximizing the quality at the expense of increased use of network resources [10].

The network control mechanisms and algorithms used by the QoE management system range from traffic shaping, traffic prioritization, and provisioning actions to access network selection and admission control. On top of the network level management operations, control operations can be performed also on application level, e.g. adapting the bitrate of a video stream to match the available link capacity for example by dropping frames or changing codec parameters, etc.

The architecture defined in IPNQSIS allows controlling the traffic users are generating in the managed networks. Service Providers use a series of limited resources shared by all users equally. This implies that under certain circumstances the quality offered and the quality experienced can be diminished, and it is not possible to take effective corrective actions.

To address these issues, we propose a solution that may act on the network to adequately manage the available resources according to certain information (user profiles, contracted services and QoE information) and a series of pre-defined policies. This architecture includes an information model that introduces the following entities:

- Management Data: Provides information to determine, in real time, the network state, and it is the data source that feeds the control component. In particular, any assumptions about QoE metrics, QoS metrics, application-level data, etc. that might be needed for the components to work as expected are classified as Management Data.

- Control Manager (CM). Receives real-time management data, the users in the network and the services requested, to determine what the state the network is, and thereby apply the necessary mechanisms to guide their behaviour, if necessary. These criteria are transferred to an intervention manager, which depends on the attributes listed, and applies corrections, as needed, on the network. The CM also must have user and service models, and be able to establish certain policies for action on the intervention system.

- Intervention Manager (IM). It consists of a device or network node itself, which incorporates a number of functions to act on the network. Its operation is based on the management of certain network resources and control policies as dictated by the Service Manager. Therefore the IM IS implements the actual control mechanisms in the network (i.e. bandwidth). This functionality will control the network resources among conditions, according to some specific policies. Different modes of action can be implemented depending on the intended purpose, such as controlling the performance of a specific type of traffic, or controlling the mass traffic volume regardless of its nature.

Building on accurate QoE correlation models, the next step is therefore to take QoE feedbacks into consideration, and use them to adapt network properties accordingly in order to maximize users' satisfaction. In fact, the model can act not only on the regulation of technical parameters, but can also impact on any internal functionality of the network. The model could act in a closed-loop adaptation regarding two aspects: (1) internal parameters, such as bandwidth, jitter, that are quantifiable, and (2) operational mechanisms such as the routing system. Regarding this last aspect, one can envision a holistic networked-system in which the routing system is driven by the QoE feedbacks provided by end-users, but it can also be computed at each node (router) of the network. QoE feedbacks are generated by receivers (customers of multimedia streams), and are then injected in network nodes (routers), which can select the best available paths based on a learning algorithm, such as Reinforcement Learning (RL). With this end-to-end approach, we expect the network to be very reactive and self-adaptive to rapid conditions changes (e.g., link congestion), therefore optimizing user satisfaction and increasing service revenue.

IV. IPNQSIS

IPNQSIS (IP Network Monitoring for Quality of Service Intelligent Support) project is developing architecures that monitor the QoE by analysing the QoS in the network and its relationship with the users' perception. The project is studying the necessary information to design next generation multimedia networks, as well as their network management systems that have to deal with QoE and SLA (Service Level Agreement) in a scalable and robust manner. The final solution will lower costs by using a network centric approach, in contrast with current solutions deployed at border devices. IPNQSIS has leveraged IP traffic models obtained in former Celtic projects (e.g. TRAMMS [1]) to carry out real-time network measurements focused on quality degradation troubleshooting.

IPNQSIS approach is novel in the sense that it defines a Customer Experience Management System (CEMS), based on the measured QoE. Several network probes developed in the project provide such QoE. They use deep packet and flow inspection to assess the QoE by looking into the IP traffic that transport the multimedia content. Evaluation algorithms are based on the correlation between QoS and QoE, together with the mentioned traffic models. The set of these components comprises the CEMS, which is the key element in this project. IPNQSIS is developing the different CEMS modules shown in this paper. IPNQSIS results will influence service providers and network operators to monitor SLA optimally. IPNQSIS will also help in the comprehension of QoS problems by contributing to new traffic models in multi-service and multi-operator networks. In conclusion, IPNQSIS outcomes will boost the Future Media Internet, encouraging the adoption of its developments to enhance the perceived quality of multimedia services.

V. CONCLUSIONS

In this paper we have presented an overview of the Customer Experience Management system (CEMS) under development within the IPNQSIS project. On the one hand a generic overall CEMS architecture is introduced, and on the other hand it's been specialized for the IPNQSIS scope, reinforcing specific areas such as network monitoring, as well as having IPTV as a main application use case. A high-level introduction to QoE concepts has been included, and details on how the CEMS architecture proposed covers them have been provided. This architecture includes modules in three levels: Data acquisition level, Monitoring level and Control level.

The data acquisition level deals with state-of-the-art data sources currently being developed by the consortium partners. The Monitoring level gathers and processes all the information in order to feed the Control, which allows to establish a first approach to the Intelligent Management of the Customer Experience. The architecture shown in this paper is currently being developed to cover IPTV services, the focus business case that will be implemented inside IPNQSIS project. T his way future works will gather the final achieved results and show how CEMS implementation will help to handle the QoE delivered to IPTV end users.

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