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QoE-based service differentiation: an analysis of the business implications for the mobile services market

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Abstract: Mobile network operators (MNOs) face a future characterised with new challenges, such as growing data consumption, a slowdown in subscriber growth and reduced revenues due to the success of over-the-top providers. MNOs must offer affordable services and provide innovative strategies to retain current customers. Quality of experience (QoE) is a well-established methodology for measuring the overall level of customer satisfaction and has also been presented as a way to improve telecommunication services. However, there is still a lack of knowledge on how the MNOs can take advantage of QoE and its potential benefits. In this paper, we explored the implications of the incorporation of QoE feedback in mobile networks at the business level. The analysis shows that value-added offers of differentiated and personalised services can be seen as alternatives to generate new revenue streams in the mobile service market.

Keywords: quality of experience; QoE; business models; mobile networks; service differentiation.

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1 Introduction

The mobile communications market is growing as more people around the world gain access to new technology. According to the GSM Association (GSMA, 2014), this growth is reflected in the more than 7.6 billion mobile connections and operator revenues of more than US$1 trillion. This phenomenon has been accompanied by a growth in network traffic, as Cisco (2012) estimates that mobile data traffic will grow 53% from 2015 to 2020 – reaching 30.6 exabytes (EB) per month by 2020.

Even though the growing trend in both the number of connections and data traffic may represent a positive landscape for mobile operators, there have been signs from operators losing out on revenues to over-the-top (OTT) players, like WhatsApp or Skype, or suffering reductions in revenues, such as Vodafone (ranging from 0.4% to 3% in the last year), in markets like the UK, Spain and Germany (Vodafone Group Plc., 2016). Informa Telecoms (2013) forecasts mobile operators will see a decline in the SMS revenues (from US$120 billion in 2013 to US$96.7 billion in 2018) caused by the popularity of OTT messaging applications.

In this scenario, customer retention will become ever more important. Ericsson (2012) reported that almost 40% of customer turnover can be attributed to perceived low levels of quality of experience (QoE) from service providers. The study revealed that subscribers are "concerned about network service performance and they also want a better experience across their entire service life cycle" (Ericsson, 2012). In the words of TeliaSonera's Chief Commercial Officer (CCO), Hélene Barnekow, at the Mobile World Congress 2015 (Aittokallio, 2015), "While technology innovation is playing its role in the changing face of the industry, the real driver of the transformation is the customer. The industry landscape is changing very quickly, and I actually try to frame that change from two angles, one is from the customers' point of view because it's not that technology is driving customers, customers are driving us." This indicates the telecom market is adopting a new approach – a user/customer-centric paradigm.

Traditionally, the telecommunications industry has relied on quality of service (QoS) as the principal descriptor of the overall performance of their network services, as stated by different authors, such as Reis et al. (2010) and Thakolsri et al. (2009a). Even though QoS has allowed mobile operators to deploy their network infrastructure and guarantee acceptable service levels, the correlation between network performance and good user experience is not direct, as stated by Thakolsri et al. (2009b) and Cuadra-Sánchez et al. (2012). This is because QoS deals only with technical aspects, ignoring the other elements impacting users' perceptions. In that sense, the use of QoE with a user-centric approach can be an alternative to deal with the telecom industry's challenges. QoE enables a holistic understanding of the users' experiences regarding the performance of applications, services and networks, complementing traditional techno-centric concepts such as QoS.

The goal of QoE is to interpret and understand end-to-end quality, including human users' points-of-view. According to the Qualinet project, QoE can be defined as "the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state" (Brunnström et al., 2013). This definition remarks that QoE in communications services is influenced by content, network, device, application, user expectations and context of use. The use of QoE data has been proposed as a way to solve problems such as the optimisation of network resources and the customer churn experienced by mobile operators (Thakolsri et al., 2009a; Cuadra-Sánchez et al., 2012). However, there is still a gap on how to make use of QoE and what its potential benefits in the context of mobile networks are. A practical application of QoE has to consider the entire QoE ecosystem, including all the stakeholders involved in the service provision and the identification of business implications. For Liotou (De Moor et al., 2015), acquiring QoE and controlling a network in a QoE-centric way must address the following topics of interest: the definition of the mechanisms to monitor and control QoE in telecommunication networks; the business opportunities for the operator and other stakeholders assuming that QoE can be managed; the new (more active) role of the end-user in such a QoE-aware/QoE-centric network and how can the end-user be convinced to 'buy' QoE. Therefore, technical research on QoE needs to be complemented with the analysis of the business implications of using QoE as the basis of the mobile networks' operation. Thus, there is an overall research question of this paper:

- How can mobile network operators incorporate QoE feedback to improve their service offer considering technical and business implications?

Although finding a technology solution might be the first step to overcoming market challenges, it is important that a technical decision comes along with an informed analysis of the regulatory conditions for that implementation and the business implications of the proposed solution. We believe that, in order to analyse the incorporation of QoE in mobile infrastructure, it is necessary to complement the description of the technical solution with a business-model analysis that describes the alternatives the mobile networks' ecosystems might face when incorporating QoE feedback. This process requires identifying how QoE incorporation might impact the structure of the mobile ecosystem, the relationship among its different actors and the value configuration – opening the door to new business alternatives. For analysis purposes, we consider different scenarios based on a scenario-planning analysis. Value network configuration (VNC) is combined with the use of a business analysis framework to describe how value creation is affected under the different scenarios and provide insights on potential business ideas with QoE feedback incorporation.

The remainder of this paper is organised in five sections: Section 2 – background; Section 3 – method; Section 4 – QoE-aware mobile architecture; Section 5 – QoE business model analysis; Section 6 – conclusions.

2 Background

2.1 Technical incorporation of QoE in mobile network

As mentioned by De Moor et al. (2015), even though QoE can have the potential to overcome some of the mobile industry's challenges, most of the work in this field has been in the technical area, especially covering QoE modelling, estimation or measurement. Studies developed by authors such as Sacchi et al. (2011), Zhang et al. (2012) and De Pessemier et al. (2013) are representative of this type of work. On QoE modelling, authors such as Fiedler et al. (2010), Mok et al. (2011a, 2011b), and Hsu et al. (2014) have focused on developing models that can predict a user's QoE based on the analysis of QoS parameters (i.e., delay, throughput). Hoßfeld et al. (2011) extended the scope of QoE analysis by including parameters of performance applications – specifically, video stalling – in the models. Even though these studies explore QoS/QoE relation, they do not address the mechanisms to incorporate QoE data in mobile infrastructure. Considerable efforts have been focused on QoE-based management of network resources. Research work by Essaili et al. (2015) and Ramamurthi et al. (2014) has explored the use of video QoE as input for the resource management strategies. These principles are integrated with different QoE architecture proposals by authors such as Foster et al. (2000), Ameigeiras et al. (2010), Thakolsri et al. (2009b) and Gómez et al. (2013). However, these architectures focus on video services without taking into account other types of traffic. The proposed architectures do not offer details on the use of tools for monitoring application performance and finding correlations that can be used to tune the service offer in a mobile network.

In a study developed by Kim et al. (2008), the authors proposed a framework oriented to guarantee QoS/QoE in mobile internet protocol television (IPTV). The framework used information on available resources, terminal capability and user's profile details to make resource allocation decisions (redistribute the available resources) according to a desired QoE level. Obtained results showed the validity of using terminal information and users' profiles to improve network resource management. However, the authors did not give details on the incorporation of this framework in the operation of mobile networks.

With the name 'QoE-aware real-time multimedia management' or (QoE2M), Mu et al. (2009) proposed a framework that combines video assessment and QoS/QoE mapping to manage content delivery. QoE2M was able to detect congestion periods and adapt the applications according to both the network conditions and the user's terminal features. Even though the high-level description of the framework is well detailed, the implementation of the framework or its use in the context of a mobile network is not discussed by the authors.

An attempt to integrate QoE management in the context of mobile networks is presented by Fajardo et al. (2010), who proposed a QoE management system for voice over IP (VoIP) in 3G networks. Fajardo et al. (2010) identified the causes of content degradation in different segments of the network infrastructure and described the impact of degradation in the end-user's QoE. Based on this analysis, the authors presented a lightweight implementation of the framework. Implementation showed that VoIP configuration can be adapted according to the availability of network resources. However, the implementation only considered the end-to-end delay to calculate the QoE degradation. Application level information was not considered in the resource allocation decisions. In addition, further implementation aspects or the incorporation of the proposed system in a mobile network were not discussed.

Continuing with the application of QoE management in the operation of multimedia applications, Vakili and Grégoire (2012) proposed a QoE framework for video conferencing. First, the authors used subjective test to measure the quality perceived by end-users. Then, the authors identified the relation between user's QoE and parameters such as frame rate and video quantisation. Based on the results, authors showed that video parameters can be adjusted looking at the available bandwidth and expected user's QoE. As a result, Vakili and Grégoire (2012) proposed a mechanism that decides the frame rate and the video quantisation according to the bandwidth and the expected user's QoE. Although this study shows that QoE-based resource management decisions can consider the application performance, the paper did not mention alternatives to incorporate the proposed framework in the operation of mobile networks. In addition, the adjustment of the network resources was based on a stand-alone process in which the application information is not gathered in real-time.

On the other hand, Gómez et al. (2013) proposed a QoE-driven architecture for resource control in long-term evolution (LTE) networks. Even though the paper focused on the integration of the proposed architecture with LTE infrastructure, it relied on deep packet inspection (DPI) to capture relevant information on the applications used by the end-user. Furthermore, Gómez et al. (2013) did not mention the role that OTT players can have in the architecture.

Meanwhile, Kim et al. (2010) provided design considerations for the incorporation of QoE feedback in mobile infrastructures by showing that end-users can be actively involved in the process of measuring QoE and provide instantaneous feedback whenever a service disruption/dissatisfaction occurs. This information, combined with network parameters and application information can be used to detect the location of faults and the reason behind QoE disturbances. However, the authors did not implement a technical solution based on their design considerations.

On the other hand, Zhang and Ansari (2011) affirmed that incorporation of QoE into next generation infrastructures (NGN) needs to consider both the network and the application layers. The authors described a general end-to-end QoE assurance system able to degrade QoE when the network resources were not sufficient. Similar to Kim et al. (2010), Zhang and Ansari (2011) referred to the challenges of the QoE incorporation, but they did not define any mechanism to interactively capture information from the user's terminal.

Finally, Menkovski (2015) introduced a QoE management framework for an IPTV service by introducing the importance of deploying probes to collect quality performance indicators (QPI) that can be used by the service provider to define and execute resource management strategies. However, the solution proposed by the author limits its approach to a fixed network environment without considering the implications of probing/monitoring systems used in the mobile networks context. Described works coincide in the importance of incorporating QoE in the operation of network infrastructures. The authors have proposed different alternatives and design considerations to achieve this goal. However, the incorporation of QoE in mobile networks needs more discussion, especially with regard to the definition of the mechanism to incorporate QoE feedback and make use of this feedback in both the technical and business operation of mobile infrastructures. Our research has proposed a technical mechanism to incorporate QoE feedback in mobile networks (Ballesteros et al., 2012) and discussed the potential benefits of this incorporation, including energy-saving considerations (Ballesteros et al., 2016a).

2.2 Business analysis of the incorporation of QoE feedback in mobile networks

Academic research recognises the potential of using QoE to improve the mobile network business. According to Aznar et al. (2011), the integration of QoE in the value chain of mobile actors might be a mechanism to increase telecommunication (telco) revenues. Perkis et al. (2014) acknowledges that "the change of paradigm towards QoE has consequences for corresponding economic and business models in the telecommunications market." For De Moor et al. (2015), research on QoE should push the transition from the QoE assessment to the generation of business opportunities assuming that QoE can be managed. Even though the aforementioned studies state that QoE is linked to the potential for increased revenues and reduced customer turnover, the research on QoE in the business domain has been rather scarce, focusing mainly on areas such as customer experience management (CEM), QoE-based service level agreements (SLA), QoE-based charging and end-users' willingness to pay.

Aznar et al. (2011) explored the integration of QoE within the value chain of mobile business actors as a mechanism to increase their revenues. Meanwhile, Perkis et al. (2014) developed an analysis of the mobile ecosystem actors and their relationship with

QoE. However, these studies have mainly focused on a generic business analysis that does not consider the implications of a technical solution to incorporate QoE in the VNC. In addition, the business considerations of these studies do not include regulatory elements in the analysis of QoE.

Stojanovic et al. (2015) pointed out that the "development and implementation of QoE-aware business models and the definition of appropriate SLA is needed when addressing the QoE management issues." On the other hand, Frangoudis et al. (2014) proposed an SLA selection framework that incorporates the desired user's QoE considering budget constraints. Authors demonstrated its application in a cloud-based teleconferencing service without considering how the framework will impact the telco market.

Varela et al. (2015) argued that the "introduction of experience level agreements (ELA) based on QoE would provide a key step towards being able to sell service quality to the user." The authors investigated alternatives to exploit QoE for improving SLA and discussed challenges and problems of the proposed approach. In the same paper, Varela et al. (2015) remarked on the need for applying QoE in the networks and services operation. So far, SLAs do not deal with QoE by users, which limits the possibilities for the market actors to create business models and revenue streams based on providing a minimum/differentiated QoE. According to Varela et al. (2015), challenges for achieving the goal of ELA include the definition of a structured framework that includes the ELA definition. On the other hand, more research is required on the evaluation of the marketing side and the structure of a QoE-based service offer.

On the relation between QoE and charging, Sackl et al. (2013) recognised the fact that QoE-based charging mechanisms are needed. However, it is necessary to examine with more detail the interrelation of payment and quality perception. Sackl et al. (2013) also argued that "QoE may serve as a principal tool for investigating the customers' service satisfaction which may on economic terms be related to customers' loyalty and their willingness to purchase network products" (Sackl et al., 2013).

Wahlmueller et al. (2012) proposed a pricing mechanism based on quality differentiation (i.e., QoE), and Reichl et al. (2012) described the conceptual relationship between QoE and charging. In their paper, Reichl et al. (2012) addressed the question of how to charge for QoE and provided an initial indication that a stronger focus on user-perceived quality might also change the perspective on charging mechanisms. Zwickl et al. (2013) developed an empirical study to measure the users' willingness-to-pay for high definition (HD) and video on demand (VoD) services. The study focused on market entrance pricing strategies linked to the differentiation in content delivery. Finally, Nesse et al. (2015) explored the service differentiation aspect and presented a model that shows that introduction of end-to-end differentiated services can bring substantial benefits to internet service providers and demanding users, while preserving the quality of basic services. However, the use of the model requires further market considerations.

Even though current research has addressed the analysis of some of the business implications of using QoE in the mobile networks, the studies have mainly focused on a generic business analysis without considering the definition of a technical mechanism to incorporate QoE feedback in the operation of mobile networks. In addition, the business considerations of these studies do not include regulatory elements in the analysis of QoE in the context of mobile networks. This paper takes a technical mechanism to incorporate QoE in mobile networks and gives insights into its impact on the mobile operators'

business model. We have investigated the implications that the incorporation of QoE would bring to the mobile network ecosystem at the business level.

The business analysis is supported by the construction of future scenarios for the QoE incorporation according to regulatory considerations and the VNC analysis, which makes the identification of changes possible in the value creation when QoE is used in mobile networks. This analysis can be used for mobile operators and other actors to forecast and plan the required actions to implement new services and business models based on the use of QoE data.

3 Method

The goal of this paper is to analyse how mobile network operators can incorporate QoE feedback to improve their service offered regarding technical and business implications. The technical mechanism considered in our analysis is devised and presented in Ballesteros et al. (2012, 2016a, 2016b), and this process has been supported by a systematic review of the literature on business analysis and related research work.

Together with the literature analysis, two workshops were organised in Kista (Sweden) in February and May 2016 with the participation of nine representatives of the mobile ecosystem. The workshops were part of the seed project 'QoE and net neutrality' funded by Wireless@KTH and involved key actors in the telecom industry – mobile network operators, network equipment vendors, regulatory authorities and representatives of telecom services' users. The summary of workshops participants is presented in Table 1.

Table 1 Participants in the first and second workshops (held in February and May 2016)

Company	*Position or unit*	*Company's role*
Ericsson	Research	Network equipment vendor
Ericsson	Business development	Network equipment vendor
Telia	Business unit	Mobile network provider
Tele2	Product management	Mobile network provider
Tele2	Customer experience	Mobile network provider
Telenor	Research	Mobile network provider
Telenor	Business unit	Mobile network provider
Edgeware	Chief technology officer	Network equipment vendor
Nätverket för Telekomanvändare – NTK	Consultant	Association of business users of telecommunications

Even though no content or service provider representative participated in the workshop, the network equipment vendors and the mobile operators shared their knowledge on the content provider's role.

The first workshop revolved around the current market structure – the role played by each actor and the implications of the incorporation of QoE feedback in the mobile industry. As a first step, participants were asked to describe their role and interactions with other actors in the mobile ecosystem. The second step focused on understanding how each actor viewed QoE and the level of importance given to this concept. The third

step centred on a future workshop (FW) activity used to define the initial elements to be considered in the analysed scenarios. The concept of an FW goes back to the ideas of Robert Jungk on how to involve people into the decision-making process and was first published in *Future Workshops: How to Create Desirable Futures* (Jung and Müllert, 1987). The method helps planning and forming the future by finding the causals, creating a vision and defining aims. The final outcome was discussed in a reflection session among all project partners.

A combination of the discussion with participants and literature review was used to obtain the key uncertainties and trends. The key uncertainties and trends are used in the definition of the final scenario matrix. The next step in this work was the definition of some analysis scenarios, which included the identification of the actors, the relations between actors (technical, business) and the variables to be considered in the scenario construction. The goal was capturing a range of possibilities for the implementation of the technical solution. A scenario planning method proposed by Schoemaker and Mavaddat (2000) is the tool proposed for this purpose. Scenario construction is based on the identification of trends and uncertainties at technical, business and regulatory levels regarding the incorporation of QoE in mobile networks. In addition, the scenarios were discussed with experts from Telenor. This information was complemented with some references on mobile network ecosystems and the mobile industry structure (Kilkki, 2008; Peppard and Rylander, 2005; Zhang et al., 2014; Funk, 2009).

The obtained scenarios were analysed in more detail through a value network analysis combined with a business model analysis framework. The goal of the analysis was to identify how the incorporation of QoE in mobile networks might affect the value creation process and change the relation between stakeholders. This analysis also provided insights on the business alternatives based on the QoE incorporation under different regulatory conditions. VNC analysis was based on literature review and elements identified in the second workshop organised with the participants in the research project 'QoE and net neutrality' and detailed in Table 1. During this workshop the participants were asked to provide insight on potential business models inspired by Osterwalder et al.'s (2010) framework.

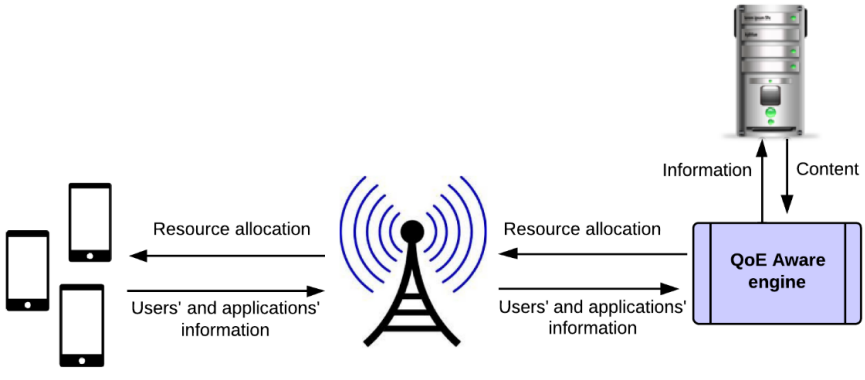
Structure of the value networks was also shared and discussed with some stakeholders in the mobile market to address realistic concerns. We developed a value network analysis based on the methodology proposed by Peppard and Rylander (2006) and adopted the VNC approach presented by Casey et al. (2010) to represent the different relations between actors.

To analyse the impact of incorporating QoE in mobile networks at the business level, we have used the scenario planning method and VNC combined with a business model analysis framework. With scenario planning, we could identify trends and uncertainties in the development of mobile networks with regard to the incorporation of QoE while describing the alternatives the mobile network ecosystem might face with this technical development. The scenario analysis considers the role of net neutrality (NN) regulation on the business alternatives within the mobile network scenarios. The considered scenarios give boundaries to how the business models and the value network could configure around QoE incorporation and give a rough idea of the power positions of the relevant actors.

VNC is used to describe how the value configuration is affected under the different scenarios and provide insights on potential business ideas with QoE feedback incorporation. Each value network is analysed using a business model framework defined for that purpose. The combination of scenario planning, VNC and business analysis can facilitate the identification of the business implications of incorporating QoE in the operation of mobile networks. On one hand, it provides a description of the evolution paths for QoE incorporation considering the effect of the market evolution. On the other hand, it facilitates the recognition of business opportunities within each one of the proposed scenarios.

The first step in the scenario planning is the identification of the two most important uncertainties, which was achieved by exchanging ideas with relevant mobile network actors during the workshops carried out in Kista. Incorporation of QoE feedback in mobile networks would require mechanisms to capture/collect QoE-related information and the implementation of resource management strategies that make use of the captured data with a business goal. Therefore, it is important to consider how the regulatory framework can affect the incorporation of QoE in mobile networks and the implementation of the required technical mechanisms. The implementation of QoE-aware architecture and the use of users' feedback in service provision will evolve around it. Current regulatory discussion is focused on NN principles and the rules to guarantee that no content or application will be favoured or blocked based on commercial goals.

Figure 1 Scenario matrix (see online version for colours)



The second most important uncertainty regards who is responsible for QoE incorporation – the MNO or the OTT provider? This aspect can impact the mobile networks' industry structure, the relation between MNO-OTT and the level of competition between these two actors. Combination of uncertainties brings different scenarios, with specific characteristics and outcomes. We defined one scenario for scenario matrix quadrant. The scenario matrix and the scenario names are presented in Figure 1.

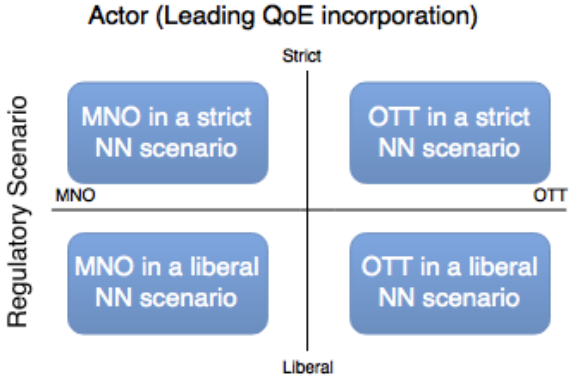
4 QoE-aware mobile architecture

Traditionally, monitoring and assessment of QoS/QoE in mobile networks rely on analytics and reporting indoor testing, drive testing and network diagnostics. Even though

these methods offer important and relevant data at the network level, they do not provide metrics on application performance or the real user's experience, as stated by Paolini (2016). Besides monitoring the traditional network, it is important to combine network data with information from the user's side in order to have more elements to deploy QoE-aware infrastructures, as stated by Kim et al. (2010) and Zhang and Ansari (2011).

We propose an alternative based on monitoring tools at the application level. In this case, users can download a monitoring application introduced by Ballesteros et al. (2012) in which is able to report performance indicators both on the app and network level to a database for later analysis. Different from traditional crowd-source approaches, like the one proposed by Hoßfeld et al. (2011) in which users run tests and later send reports, we propose automatically monitoring, collecting and reporting data. Figure 2 shows the different components of the proposed architecture.

Figure 2 Main elements composing the QoE-aware system (see online version for colours)



The main element in the architecture is represented by the QoE-aware engine, which is responsible for collecting the information provided by the user's terminal. It takes care of profiling user requests as well as keeping track of the terminals and the current status of content processing. Collected information includes app name, category, session duration, network type (EDGE, UMTS, HSPA, HSDPA, HSPAP or LTE), uplink and downlink throughput, dropped packages, duration of timeouts, interruptions in the content display and signal strength. These parameters feed a QoE model which estimates QoE levels based on evaluation of parameters and is used at the moment of assigning network resources. Information is submitted from the mobile terminal using a monitoring application which starts collecting and reporting data when the user starts an app (e.g., YouTube). The monitoring application requires the establishment of a radio bearer between the terminal and the base station in order to send the QoE-associated information. In that sense, the terminal has to initiate an attach procedure when the user's application starts.

Demonstration of the monitoring tool and its use in the mobile networks concept was performed by Ballesteros et al. (2016b) in the paper 'Effects of network performance on smartphone user behavior'. Empirical testing and statistical analysis were supported using Ericsson Apps (EA), an app engine for Android smartphones developed and provided by Ericsson as part of the research project 'QoE: an analysis from a techno-economic perspective'. The use of information provided by a monitoring tool to

activate a resource management decision was then evaluated through extensive simulation of a mobile network in a video streaming scenario which evaluated the impact of different resource schedulers fed with data on the applications' performance. Performance indicators for the system operation included frequency and length of video interruptions, while the goal of the system was to reduce the number of interruptions experienced during the playback, as presented in Ballesteros et al. (2012, 2016a).

The main advantages of the proposed approach include the following:

- Collecting data is not expensive because it is supported by the installation of a simple application.
- Information can be gathered in real-time, which might support adjustment of network resources on the fly.
- It provides the ability to conduct historical trend analysis and the capacity to identify application usage patterns so that they can be correlated with network indicators and used to improve/optimise network performance.
- It can provide accurate information on the device and its location, which can be used to activate network functionalities or new charging plans.

5 QoE business model analysis

Currently, different frameworks are used to analyse business models. Osterwalder et al. (2010), uses an industry-generic business model framework consisting of nine different design units, referred to as building blocks. Bouwman et al. (2010), on the other hand, uses a service, technology, organisation, technology (STOF) step-by-step framework for analysing business models for mobile service innovations. Osterwalder's framework is favoured and, to a great extent, applied within different industries today. The nine building blocks or elements are grouped into four major blocks – offer, customer, infrastructure and finance – as proposed and described by Nesse et al. (2011) and presented in the following:

- *Offer* (*value proposition*)*:* this block identifies the benefits a company offer to its clients through solving their problems with the company's services or products.
- *Customer* (*customer relationships*, *customer segments and channels*)*:* this block identifies the client segments for the products and services. It also describes how these segments are interfaced. Relevant issues here are the distribution channels.
- *Infrastructure* (*key partners*, *key activities and key resources*)*:* this block identifies the key processes and activities for creating the product or service that the company offers.
- *Finance* (*cost structure and revenue streams*)*:* this block identifies the cost structure of the business, whether the costs are fixed or variable, operational (OpEx) or investments (CapEx), and, finally, the associated risks.

As QoE information could be utilised in multiple use-cases, the business analysis does not focus on a specific core service but, rather, at how the actors' roles and their technical components could be arranged in the market and what conclusions may be drawn. This

assumption does not alter or limit the roles that need to be fulfilled in order to deliver any type of service using the QoE information captured with the technical solution proposed in this paper. In that sense, we support our analysis in the combination of the proposed business analysis framework with the VNC of each proposed scenario, considering the potential changes identified. The technical components in each role may need some changes depending on the actor implementing the QoE incorporation – for example, software/hardware elements to implement the solution – but the roles and their allocation to actors would remain with no changes. According to the results obtained in the workshops, the main roles that need to be fulfilled by the different actors in the value network are listed below:

- *Application/content provisioning:* related to the provision of application functionality and associated services/content over the network to the end-user.
- *Wireless access network* (*WAN*) *operation:* this role covers maintaining and operating the access and core network infrastructure. It also includes the connectivity provision to the end-user.
- *Usage:* this role denotes the consumption of the mobile services and applications.

Apart from the main roles, which are part of the mobile networks' VNC, two additional roles are identified, relating to the incorporation of QoE in the mobile network operation and the role that regulatory framework plays in the considered scenarios. These new roles are as follows:

- *Regulation definition:* this role covers the regulatory activities and policies that may affect the way different actors exercise their roles in the value network.
- *Quality provision:* this role covers all the activities required for incorporating QoE feedback in the operation of the mobile networks' service provision and the actions that can be taken to offer differentiated services – for instance, traffic management/prioritisation actions.
- *Monitoring:* this role is related to the activities required to capture QoE data on apps, network and end-users.

In the following, we describe the different configurations/scenarios that emerge around the incorporation of QoE feedback in mobile networks. Each oval represents a technical component, while the red lines between the technical components show the technical interfaces as well as the functional protocols of the technologies used in the technical components. The black lines represent the business interface between the actors, such as contracts and monetary exchanges. The business analysis of each scenario focuses on the four elements of the proposed framework, which are intended to help the stakeholders involved to address the industry changes in a new manner. The information used in the analysis is based on public information as well as discussions with the participants in one of the workshops of the QoE and NN organised in Kista and described in the methodology section.

5.1 Scenario 1 (QoE incorporation led by MNOs in a strict NN scenario)

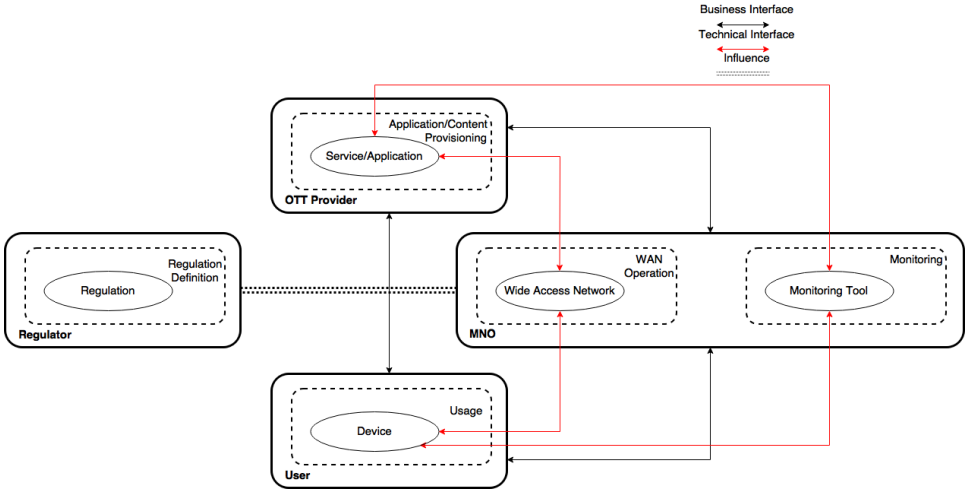
In this scenario, presented in Figure 3, the QoE incorporation mechanism resides with the MNO (FION approach). The regulator would set strict rules on NN that do not allow any

kind of commercial agreement to favour one OTT provider over the others. In the same vein, MNO could not work on commercial offers based on content segmentation/classification that require throttling, blocking or content prioritisation.

Network operation would be based on the best-effort principles, and the regulator would only allow the implementation of 'reasonable' resource management principles (e.g., radio resource management, routing policies at the core network) to allow for network operation. This network practice must be primarily used for network management and not for business purposes. Users would pay for mobile broadband data plans based on capacity and could have one MNO contract and many business relationships with different OTT providers. As long as the user authorises it, MNO could implement a mechanism to monitor the network operation as well as keep track of the users' experience with the service provision, collecting information from the users' devices.

- *Offer* (*value proposition*): as depicted in Figure 3, the MNO and OTT would keep the business interfaces formed with the end-users. The MNO provides ubiquitous communication services (physical connectivity) to end-users, giving them access to their network and different content/application services. End-users would pay for this access with a subscription/usage fee determined by data capacity. With the use of QoE data, MNOs could get a better understanding of the users' interests and profiles, the usage of applications and the impact of network performance on QoE. This information can be used by MNOs in the network improvements (coverage and capacity) to offer users non-disrupted and fast access to their favourite applications/contents.

Figure 3 VNC for scenario 1 (QoE incorporation led by MNO in a strict NN scenario) (see online version for colours)



The OTT provider would offer different application-related services and relevant data and information products, such as news, music and video, and distribute them using the mobile channel. In this scenario, the business interface between the OTT and the user (presented in Figure 3) may or may not involve money exchange since

the user gains value by using the service and the OTT may find value by having the user's attention and offering its platform for marketing operations.

Figure 3 shows that a business interface could be created between the MNO and the OTT provider based on the exchange of collected QoE data by the MNO. Information on network performance, patterns of usage and trends may be of interest for OTT providers interested in both improving their commercial relationship with the end-users by knowing more about them and improving the applications and content use of network resources to reach their customers.

- *Customer* (*customer relationships*, *customer segments and channels*): according to the workshop results, the value proposition of MNOs and OTT providers could be directed to the traditional segments – consumers and business. Segments based on data plans or price continues to be implemented. However, the accuracy of the gathered information by MNO might improve the scope of the offers aiming at more granularities within the broad group of users. In this scenario, OTT providers might get similar benefits, which are complemented with the knowledge they can capture on network performance and its effect on the usage of the applications. An alternative would be the categorisation of the users according to their level of consumption – by volume or time. For the business market, QoE differentiation might target premium corporate users targeting not only the standard quality requirements but the specific business considerations regarding security, reliability and stability during critical business sessions, as well. MNOs consider they might get benefits from a closer relationship with the user through an efficient use of the collected QoE data. The operators can establish relationships with its customers through a price plan based on the identification of consumption trends and app usage patterns and build this relation with direct communication about their interest in the service provision and the service quality perceived.

  With regard to how the MNO might communicate the value proposition to the customers, this would happen through MNO's retail network, web platform and its partners' channels. An additional channel can be through stronger presence in social networks and media. On the other hand, content providers can reach their customers using their web channels as well as partners' ecosystems.

- *Infrastructure* (*key partners*, *key activities and key resources*): in this scenario, MNO leads the incorporation of QoE in the operation of mobile infrastructure. In addition to the WAN operation role, according to participants in the workshops, the MNO can undertake the monitoring role to capture QoE-related data as long as the MNO and the end-users sign a transparency agreement in which end-users authorise the MNO to collect apps/user data for the use of commercial purposes. The monitoring tool is a software app with the capacity to collect data from the terminal on the application/end-user and network performance and report. Its development may be the responsibility of the MNO, an independent software developer or the result of an alliance between OTT provider and MNO with a common purpose. Therefore, software development resources (e.g., platform, developers) are required by the MNO to implement the monitoring tool.

  The importance of the monitoring role here is directly dependent on the use of the collected information. On one hand, in this scenario, MNOs would consider using

the QoE data to improve both the network and business operation. Network operation improvements can be guided by a better understanding of the use of network resources, which can lead to capacity and coverage expansions. At the business level, the use of QoE data can be used to get a better understanding of users' demands and expectations so that the MNOs can structure its commercial offers. MNOs could sell the collected information to those OTT providers interested in getting more insight on the users' QoE/application performance/network performance.

Due to the restrictions on NN, the MNOs could not use the QoE data to offer services based on paid prioritisation. However, the participants in the workshop agree that the offer of specialised services or zero-rating plans may take advantage of the collected information and drive the way these commercial offers are structured. Regulators in this case would be responsible for studying the legal feasibility of the commercial offers proposed by the MNO or its associates.

Participants in the workshop consider that the OTT provider keeps its role as application/content provider, which, in this scenario, is benefited by the network improvements driven by the use of QoE data and implemented by the MNOs. Access to the monitoring information might generate additional benefits for the OTT provider, which can use the obtained data to improve the application operation and the content distribution. Data obtained through the monitoring tool can include content/application use of resources, trends on apps and content consumption and patterns of usage by the application. End-users (private and corporate) consume the content provided by the OTT provider and continue using the MNO's infrastructure.

With the expansion in the capacity and coverage of the network and the improvements in the applications/services performance, the end-users would obtain improvements in their QoE.

- *Finance* (*cost structure and revenue streams*): the MNOs will typically have costs related to the deployment and operation of its infrastructure. By assuming the monitoring role in the value network, the MNOs would assume the costs associated with developing and running the monitoring tool. This includes the development of a software platform and the human resources required to create and operate the monitoring system. In addition to these costs, MNOs would have to assume the costs of the billing system, the administration of its customer base and the activities of marketing and support linked to the service offer.

  In regard to the OTT provider, participants in the workshop foresee that costs will be linked to the application/content development, the integration and application management (versioning, portability checking), the operation of the required infrastructure for its operation as well as the investments on technical/customer support and consulting services. With the implementation of the monitoring by the MNO, the OTT providers may need to access the collected information, which would also generate a cost for the OTT provider.

  Regarding revenue streams, MNOs might continue with revenues attached to subscription fees. In addition, the use of QoE data could create a new revenue stream by commercialising the collected information for OTT providers or other businesses

interested in a closer relationship with the end-user. It might be possible to generate revenues by either assessing fees for ads in content or charging the content/service provider to guarantee users' access to their services even when 'there are no bits in the bucket' or zero-rating. However, this case needs to be studied in light of the regulatory framework. Meanwhile, OTT would not experience a change in the traditional revenue streams.

5.2 Scenario 2 (QoE incorporation led by OTT provider in a strict NN scenario)

Within this strict NN scenario, presented in Figure 4, the OTT provider would act as content distributor and the MNOs as a pipeline. MNOs cannot engage in 'paid prioritisation' practices, and network management mechanisms are allowed only with technical purposes, not commercial ones. As such, disclosure of network management practices to consumers is required. This scenario represents an OTT approach in the implementation of the QoE-aware engine.

In this scenario, the OTT provider could implement mechanisms to improve the quality of the content received by the customers (e.g., compression mechanism, pre-buffering, etc.). With the authorisation of the end-user, the OTT provider could monitor the quality perceived by the users on the content provided, as presented in Figure 4. However, the gathered information could not be used to implement the network management mechanism oriented to prioritise any type of content.

- *Offer* (*value proposition*): in this scenario, the business interfaces towards the end-user remain intact, as shown in Figure 4. The MNOs would continue providing ubiquitous communication services (physical connectivity) to end-users, giving them access to their network while making it possible for the end-user to enjoy the different content/application services of their interest. On the other hand, the OTT provider would offer different application-related services and relevant data and information products, such as news, music and video, while using the mobile channel to distribute them among the end-users.

  For the participants in the workshops, the OTT could have more details on users' QoE, trends and patterns of consumption with the monitoring tool under its control (Figure 4). This could be used to offer content/applications based on the specific customer demands. For instance, the quality of the content (e.g., video resolution) could be adapted according to the users' terminal considering screen size, light conditions and proximity to the end of the data cap or the users' location and type of network connection.

  In this scenario, the business interface between the OTT and the user may or may not involve money exchange, and the grade of service personalisation can lead to different price schemes/segments. Another revenue source for the OTT provider would be the commercialisation of collected information. Some of the OTT provider's customers could find value on a high granularity level in the customers' information in order to structure commercial offers of high interest for users due to matching the commercial offer with the users' interests.

- *Customer* (*customer relationships*, *customer segments and channels*): within scenario 2, the value proposition of MNOs and OTT providers could be directed to

the traditional segments – consumers and business. Segments based on data plans or price continue to be implemented; however, the OTT could also have business alternatives by commercialising the collected QoE data to MNOs interested in using the information to improve their network performance and to other commercial companies interested in reaching end-users with their services and products.

In this scenario, the OTT provider could apply its knowledge on end-users' interest and profiles to deepen their segmentation/categorisation according to type of content consumed, levels of consumption and their interest on high or standard content quality. For the business market, QoE differentiation might target premium corporate users focusing not only on the standard quality requirements but, specifically, security, reliability and stability during critical business sessions.

From our point-of-view, the OTT provider would benefit from a closer relationship with the user through efficient use of the collected QoE data. The OTT provider could establish relationships with its customers through a price plan based on the identification of consumption trends and app usage patterns and build this relation with communities via direct communication about their interest in the service provision and the service quality perceived.

With regard to how the OTT provider communicates the value proposition to the customers, this would occur via the web platform and through partners' channels, which can be MNOs paying for access to the information captured with the monitoring tool. An additional channel can be the through stronger presence on social networks and media. On the other hand, MNOs can reach their customers using their traditional retailers and channels such as web channels.

- *Infrastructure* (*key partners*, *key activities and key resources*): in this scenario, the monitoring role is assigned to the OTT provider instead of the MNO, as depicted in Figure 4. Therefore, the OTT provider captures the QoE-related data with no intervention by the MNO. Scenario 2 is characterised by the strict regulation on NN, which affects most possibilities of the MNO to develop business alternatives based on traffic management and prioritisation. In contrast, OTT providers would not see strong limitations on their commercial alternatives since they are the engine behind the virtuous cycle, as stated by the FCC (2015). Exceptions can cover zero-rating or other commercial alliances with the MNO.

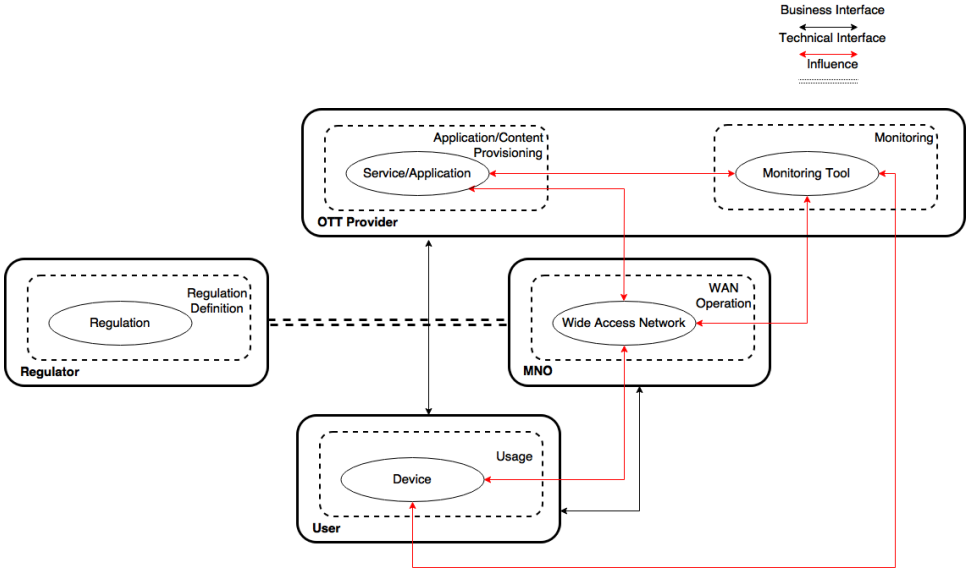
  Besides the monitoring role, the OTT provider would maintain its role as application/content provider, impacting the MNO and its WAN operation role (Figure 4). By implementing the monitoring role, the OTT provider could increase its awareness of the end-users' patterns of usage and data consumption, which can be used in both a granular profiling aiming at commercial goals and the improvement in the use of network resources by the content/applications developed by the OTT provider.

  In this scenario, gathered information can be added to the users' profile data already collected by the OTT provider increasing the commercial value of this information in the transactions with other organisations. End-users would be required to sign a transparency agreement in which they authorise the OTT to collect apps/user data and use it for commercial purposes. As described above, the monitoring

tool is a software app with the capacity to collect data from the terminal on application/end-user and network performance. The OTT provider may develop the software tool or hire an independent software developer.

OTT provider could use the QoE data to improve the use of network resources – for instance, less bandwidth requirements – and get more insights on user behaviour, which may result in more personalised/customised offers with commercial benefits. The OTT provider might develop the monitoring tool for its own benefit, collecting data strictly related to its content/application or develop a generic tool with the potential to collect other OTT providers' data. In this last case, through a commercial agreement, the monitoring tool developer could sell the required data to the interested stakeholders.

Figure 4 VNC for scenario 2 (QoE incorporation led by OTT provider in a strict NN scenario) (see online version for colours)



Meanwhile the MNOs would continue operating the network – assuming a pipeline role – with no direct use of the QoE data in its commercial strategies. With OTT providers playing a central role in the value network, the growing trend on content/application demand is expected to continue, which would force the MNO to keep investing on network capacity to respond to the demand for more content. Therefore, MNOs see that they will continue facing a situation similar to the current one – high demand on network resources and quality but few revenue stream alternatives. However, zero-rating packages could be offered as a result of MNO/OTT provider alliances. In this case, the regulator would continue with the role of evaluating and defining the legal feasibility of such commercial offers.

Finally, in scenario 2, the end-users (private and corporate) are expected to have a closer relationship with OTT providers due to the increase in the level of customisation/personalisation in the services offered. End-users would continue with

their usage role, consuming the content/applications provided by the OTT provider while using the MNO's infrastructure by paying a subscription fee.

- *Finance* (*cost structure and revenue streams*): in this scenario, it is foreseen that costs for OTT providers are linked to the following: the application/content development; the integration and application management (versioning, portability checking); the operation of the required infrastructure for its operation; the investments in technical/customer support and consulting services. By assuming the monitoring role, the OTT provider would assume the cost of developing and running the monitoring tool. In addition to these costs, the OTT provider could assume the costs of the billing system, the administration of its customer base and the activities of marketing and support linked to the service offer.

  On the other hand, the MNO costs would be associated with the deployment and operation of its infrastructure. Other costs for the MNO can include the billing system, the administration of its customer base, marketing and customer support. In addition, MNO could incur additional costs associated with buying QoE data for improving its network operation from the OTT provider. Regarding revenue streams, in addition to the traditional OTT provider's revenue streams (e.g., subscription fees, advertisement), the OTT provider could sell QoE data to those MNOs interested in improving network performance. QoE data may also be sold to other companies interested in getting a closer understanding of users' profiles to reach them with commercial products and services.

  Meanwhile, the MNO would continue with revenues attached to subscription fees. It might be possible to generate revenues by charging fees for ads in content or for charging the content/service provider to guarantee users' access to their services even when 'there are no bits in the bucket' or zero-rating. However, this case needs to be studied in light of the regulatory framework.

5.3 VNC and business analysis for scenario 3 (QoE Incorporation led by MNO in a liberal NN scenario)

In the third scenario represented in Figure 5, the market is self-regulated. MNO could offer differentiated services based on monitoring users' QoE and their expectations, and zero-rating and specialised services might be developed with no regulatory restrictions. This scenario would include commercial agreements between MNOs and OTT providers to offer fast lanes and activate paid prioritisation. Therefore, MNOs might generate new revenue streams by favouring OTT providers/type of content over others.

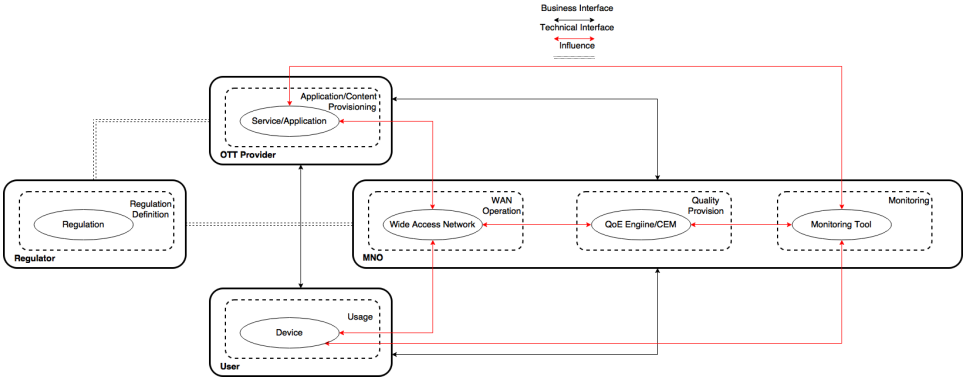
Conversely, MNO could offer QoE-differentiated services and contents and charge customers for this differentiation. In this scenario, resource management policies are implemented considering both the technical performance and the commercial goals of the MNO. Users would have the opportunity to pay for QoE-differentiated services and content adjusted to their requirements and needs, not only attached to a data capacity plan.

As presented in Figure 5, MNOs would use, monitor and capture QoE data from end-users' devices, using this information to implement mechanisms to manage/prioritise traffic as the basis of its commercial offers. MNOs would have the opportunity to share with or sell to OTT providers the QoE data captured using the monitoring tool. In

addition, MNO could segment its customer base according to the expected QoE, the type of content or the priority users want to pay for.

- *Offer* (*value proposition*): it is foreseen that, in this scenario and as presented in Figure 5, the MNOs and the OTT providers would keep the business interfaces formed with the end-users, which implies a transaction between the end-user and the MNO based on the use of the network capacity as a platform to receive and share content/applications. On the other hand, the end-user would maintain the business interface with the OTT provider based on access to different types of content and services. In addition to the aforementioned business interfaces, a new business channel would appear between the OTT provider and the MNO (Figure 5). This business interface would represent commercial exchanges based on paid-prioritisation (access to fast-lanes offering better network conditions) and the commercialisation of QoE data obtained through the monitoring tool. Information on network performance, patterns of usage and trends may be of interest for OTT providers who aim to improve their commercial relationship with the end-users by knowing more about them and improve the applications and content used by their customers.

Figure 5 VNC for scenario 3 (QoE incorporation led by MNO in a liberal NN scenario) (see online version for colours)



With the monitoring tool and assuming the quality provision role, the MNO might get closer to the user's expectations, profiles and demands. This information can be used to offer personalised services, including tailor-made content distribution, adapting the content delivery to the users' demands on favourite applications, a guaranteed throughput level to support the applications or recommending content features or applications that make better use of the available network resources or the plan paid by the end-user. Within this scenario, another revenue source for the MNO could come from the paid prioritisation schemes in which the MNO guarantees to special OTT provider fast-lanes and high-level network performance (previously stipulated in SLAs). In this case, the OTT provider could have exclusive access to more network resources and improve the content distribution/application performance while guaranteeing good users' QoE.

- *Customer* (*customer relationships*, *customer segments and channels*): with the possibility to implement traffic management/prioritisation techniques in the network

operation, MNOs have foreseen a segmentation of the customer base into different categories (e.g., premium, non-premium users), considering their interest in paying for specific quality levels associated with different types of content. Segments based on data plans or price could be implemented, as well. The accuracy of the gathered information by MNO might be used to improve the scope of the offers aiming at more granularities within the broad group of users. For the business market, the differentiation based on QoE might target premium corporate with specific business considerations of security, reliability and stability during critical business sessions.

MNOs would benefit from a closer relationship with the user through an efficient use of the collected QoE data. In this scenario, the operator can establish relationships with its customers through a price plan based on the identification of consumption trends and app usage patterns and build this relation with direct communication about their interest in the service provision and the service quality perceived. With regard to how the MNO would communicate the value proposition to the customers, this could occur through MNO's retail network, web platform and partners' channels. An additional channel might be through a stronger presence on social networks and media. Contrarily, content providers could reach their customers using their web channels as well as partners' ecosystems.

Within this scenario, the OTT provider would buy the QoE data captured by the MNO applying this knowledge on end-users' interests and profiles to deepen their segmentation/categorisation. The OTT provider could establish relationships with its customers through a price plan based on the identification of consumption trends and app usage patterns and build this relation with communities via direct communication about their interest in service provision and the service quality perceived.

- *Infrastructure* (*key partners*, *key activities and key resources*): scenario 3 represents the incorporation of QoE in the network led by the MNO within a liberal regulatory scenario. This represents low regulatory barriers regarding NN. Therefore, the MNOs would assume the roles of operating the network infrastructure, monitoring and quality provision, as depicted in Figure 5. This last role is supported by the QoE data captured from the users' devices.

  Within this scenario and in addition to the implementation of the monitoring tool, the MNO would require deploying a quality provision platform, which includes software/hardware-based solutions to offer QoE-based services. Additionally, MNOs would require changes/adjustments on its business/commercial operations in order to centre its offer on a user-centric approach. Using QoE as the basis of the business offer might require an increase in the collaboration and communication between the commercial and technical areas so that area goals can be aligned. Conversely, incorporation of QoE would require a closer relation with the user and better understanding of his/her requests and demands, which involves broadening the channels of communication with the user. As in scenarios 1 and 2, a transparency agreement between the end-user and the MNO would be required to use gathered information with commercial purposes.

  In Scenario 3, MNOs do not have restrictions on implementing traffic management mechanisms with a business purpose (e.g., offer differentiated video qualities

according to price plans) and to establish paid prioritisation agreements with OTT providers. Both cases are not banned as long as there is full transparency on the effects and implications of the technical mechanisms implemented in the network and the scope of the paid-prioritisation agreements. In addition, MNO could sell/exchange users' data, including the identified patterns and trends on applications usage, to/with those OTT providers interested on a closer understanding of users' QoE.

As presented in Figure 5, OTT providers continue playing the application/content provisioning role using the MNO infrastructure to reach end-users. However, the possibility of some OTT providers being favoured by paid-prioritisation agreements with the MNO could make the competition at the OTT level stronger. This type of agreement may close the door for those newcomers working with content whose quality highly depends on network performance and who are without enough negotiation power with the MNOs. An example of this situation is a start-up interested in offering video solutions; in this situation, regulators may intervene in order to ensure that there will not be market distortions.

In Scenario 3, OTT providers could benefit from the improvements in the network operation thanks to the use of QoE data by the MNO. However, they should consider that the conditions offered by the MNO regarding the use of the network infrastructure may change, as, in fact; the MNO could use its power to leverage their own content/application solutions. Again, the regulator has to be alert to guarantee open competition and the best interests of the users. On the other hand, OTT providers could benefit from having access to the monitoring information since they would be able to use the obtained data to improve the application operation and the content distribution. Data obtained through the monitoring tool might include content/application use of resources, trends on apps and content consumption and patterns of usage by the application.

The monitoring role is maximised by the possibility of the MNO using the QoE information in both the network operations and the commercial offers. Network operation improvements can be guided by a better understanding of the use of network resources and the definition of traffic management mechanisms oriented to get a smarter use of the network resources. At the business level, QoE data could be used to get a closer understanding of users' demands and expectations and as the basis for new business models (e.g., paid prioritisation, differentiated quality and content distribution, commercial exchange of the QoE data) and commercial offers. In this regard, the offer of specialised services or zero-rating plans may take advantage of the collected information, which can drive the way these commercial offers are structured. The regulator in this case is responsible for studying the legal feasibility of the commercial offers proposed by the MNO or its associates.

End-users (private and corporate) would consume the content provided by the OTT provider and continue using the MNO's infrastructure. With the expansion in the capacity and coverage of the network and the improvements in the applications/services performance, the end-user could obtain improvements in their QoE. In this scenario, where transparency of OTT providers/MNO with end-users is a key aspect, the end-users, with their decisions and choices, may shape the market development and motivate some regulatory decisions when necessary.

- *Finance* (*cost structure and revenue streams*): the MNO will typically have costs related to the deployment and operation of its infrastructure. By assuming the monitoring and quality provision roles, the MNO would have to cover the costs associated with developing and running the monitoring tool as well as costs associated with the traffic management/prioritisation in the network. This includes the development of a software platform, the human resources required to create and operate the monitoring and the quality provision systems and the equipment to implement tasks associated with quality provision. In addition to these costs, MNO would assume the costs of the billing system, the administration of its customer base and the activities of marketing and support linked to the services offered.

  For the OTT providers, costs would be linked to the application/content development, the integration and application management (versioning, portability checking), the operation of the required infrastructure for its operation as well as the investments on technical/customer support and consulting services. In addition, the OTT providers may incur costs for fast-lanes after signing paid-prioritisation agreements. In the same way, the OTT provider could buy QoE information to improve its relationship with the customers.

  Regarding revenue streams, MNOs would continue with revenues attached to subscription fees. In addition, the use of QoE data could create a new revenue stream by selling QoE data to OTT providers interested in using that type of information. Similarly, MNO could obtain new revenues by charging for prioritisation of content. It might be possible to generate revenues by charging fees for ads in content or for charging the content/service provider to guarantee users' access to their services even when 'there are no bits in the bucket' or zero-rating.

  The OTT provider would not experience a change in the traditional revenues' streams (e.g., subscription fees, advertisement). However, it might improve its commercial offer by buying QoE data from the MNO and using this data to improve the use of network resources and define new segments of users.

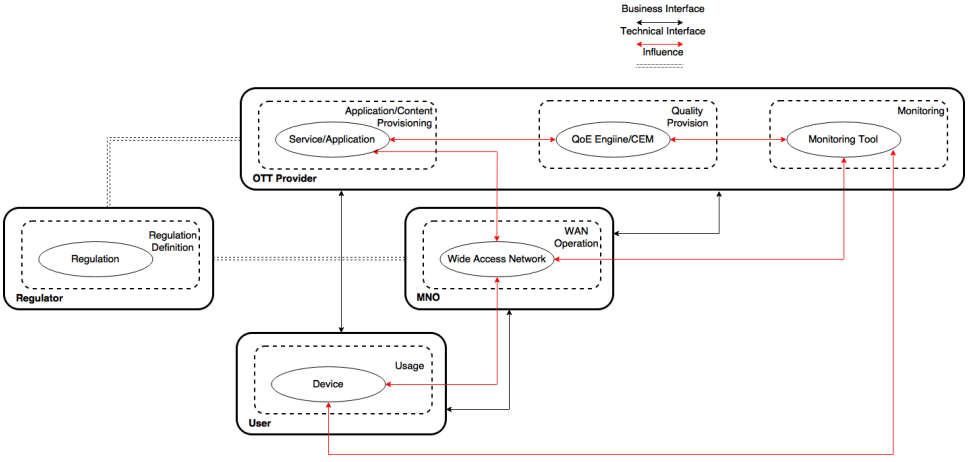
5.4 VNC and business analysis for scenario 4 (QoE incorporation led by OTT provider in a liberal NN scenario)

The fourth scenario, shown in Figure 6, is similar to the third scenario; however, the incorporation of QoE is led by the OTT provider. This means the QoE engine is controlled by the OTT, which makes it possible to monitor and capture QoE data and implement quality provision mechanisms.

In this scenario, the OTT provider could implement commercial agreements with MNOs in order to receive priority to access the network infrastructure. These agreements would also allow the OTT provider to gain access to network performance indicators and act accordingly, offering better QoE to final users. MNOs should ask the OTT provider for access to users' profiles and QoE data in order to implement resource management policies in their network infrastructure. By incorporating QoE feedback, the OTT provider might allow for cooperative work with the MNO in order to generate improvements in the services offered both at the MNO and the OTT levels. Furthermore, OTT providers could also charge for subscription and for quality level.

- *Offer* (*value proposition*): in scenario 4, the business interfaces towards the end-user do not have any changes. MNO provides connectivity service while the OTT provides the content/application the end-users demand, as shown in Figure 6. Similar to scenario 3 and due to the regulatory conditions, a business interface could appear between the MNO and the OTT provider based on the definition of paid-prioritisation agreements. In addition, the MNO might agree with the OTT provider's conditions for using the network based on the exchange of QoE data monitored and captured by the OTT provider. MNO may offer a better deal if the OTT provider facilitates access to QoE data and other relevant user information that can be used to improve the MNO's technical and business operation.

Figure 6 VNC for scenario 4 (QoE incorporation led by OTT provider in a liberal NN scenario) (see online version for colours)



In Figure 6, with the monitoring tool and assuming the quality provision role, the OTT provider would increase its knowledge-base on the end-users. With this information, the OTT provider would get closer to the user's expectations, profiles and demands; and this information could be used to offer personalised services, including tailor-made content distribution, adapting the content delivery to the users' demands on favourite applications, offering a more convenient format to deliver content according to the network conditions without affecting the users' QoE. Also, the knowledge of the end-users' profiles would make it possible for the OTT provider to recommend content features or applications that make better use of the available network resources.

Conversely, the MNO would continue assuming the operation of the network infrastructure offering to the end-users the platform to consume the content/applications provided by OTT actors. However, due to the liberal approach on NN regulation, MNO might implement paid prioritisation schemes in its relationship with the OTT provider. By offering access to fast-lanes, the MNO could guarantee to OTT providers high-level network performance (previously stipulated in SLA) so the OTT provider might have exclusive access to more network resources and improve the content distribution/application performance while guaranteeing users have good QoE.

- *Customer* (*customer relationships*, *customer segments and channels*): with the possibility to play the quality provision role, the OTT provider could segment the customer base into different categories according to identified trends and patterns of content/application consumption/usage. From the workshop discussions, the OTT provider might target premium corporate end-users interested not only in the standard quality requirements but also the specific business consideration regarding security, reliability and stability during critical business sessions. The OTT provider would benefit from getting more awareness of the end-users' interests and demands, which can also impact the level of personalisation/customisation of the content and applications provided.

  Meanwhile, the MNO could direct its value proposition to the traditional segments – consumers and business. With the possibility of prioritising traffic based on commercial agreements, the MNO might create premium and non-premium segments for the OTT providers. Additionally, the MNO could buy the QoE data captured by the OTT and apply this knowledge on end users' interests and profiles to deepen their segmentation/categorisation. With regard to how the OTT providers could communicate the value proposition to the customers, this would occur through web platform and some MNO partners' channels. An additional channel can be through stronger presence on social networks and media. Contrarily, the MNO could reach their customers using their retail channels, web channels as well as using partners' ecosystem.

- *Infrastructure* (*key partners*, *key activities and key resources*): in this scenario, the OTT provider, beyond its role as application/content provider, would be able to monitor the mobile terminal and use the collected QoE data to activate its quality provision role (see Figure 6). Here, as long as there is an agreement with the end-user, the OTT provider could use the collected QoE data for commercial purposes.

  OTT provider would assume the quality provision role, which requires developing both the monitoring tool and the quality provision platform. This includes technical and human resources required to incorporate QoE in the platform operation. Implementation of the monitoring tool and the quality provision platform may be assumed by the OTT provider or by a third-party company.

  The collected information might be added to the already-existing users' profiles, strengthening the OTT provider's knowledge on its users and interests. This could also impact the commercial value in different transactions between the OTT provider and other organisations within the business ecosystem. By implementing the monitoring role, the OTT provider could increase its awareness on the end-users' patterns of usage and data consumption, which might be used in both a granular profiling aiming at commercial goals and the improvement in the use of network resources by the content/applications developed by the OTT provider. This might be obtained by implementing proactive and real-time quality monitoring and assurance.

  Besides the possibility to compress the content demanded by the users, the OTT provider might implement new mechanisms and communication channels to involve users in the service improvements by assuming the quality provision role. In addition, the OTT provider would be able to collect data from both, its own and the

competitor's applications/content. In the latter case and through a commercial agreement, the OTT provider could sell the required data to the interested stakeholders.

MNOs would continue assuming the operation of the network infrastructure, offering to the end-users the platform to consume the content/applications provided by OTT actors. However, due to the liberal approach on NN regulation, MNO could implement paid prioritisation schemes through its relationship with the OTT provider. Conditions of these agreements will depend on the bargaining power of each actor and the elements considered in the negotiation, including the usage of the QoE data and the relation with the users. For instance, the MNO may offer a better deal if the OTT provider facilitates access to QoE data and other relevant user information that can be used to improve MNO's technical and business operation. The MNO role would then go beyond the dumb pipeline provider to reach a smarter use of the network resources but without implementing the quality provision mechanism. MNO could agree with the OTT provider's conditions for the use of the network based on the exchange of QoE information. In all commercial agreements, the regulator would take an important role defining the conditions and scope of the MN/OTT provider negotiation so that the interest of the user will not be affected.

End-users (private and corporate) will consume the content provided by the OTT provider and continue using the MNO's infrastructure. With the improvements in the applications/services performance, the end-users could obtain improvements in their QoE and, with their decisions and choices, may shape the market development and motivate some regulatory decisions when necessary.

- *Finance* (*cost structure and revenue streams*): based on the workshops' discussions, it was observed that the OTT provider would incur costs linked to the application/content development, the integration and application management, the operation of the required infrastructure for its operation as well as the investments on technical/customer support and consulting services. By assuming the monitoring and quality provision roles, the OTT provider would need to consider the costs for developing and deploying both the monitoring tool and the mechanisms to control the quality of the content provided. In addition to these costs, the OTT provider could assume the costs of the billing system, the administration of its customer base and the activities of marketing and support linked to the service offer. Paid-prioritisation agreements signed by the OTT provider might also impact its cost structure.

  Within this scenario, the MNOs would incur costs associated with the deployment and operation of its infrastructure and other costs for will include the billing system, the administration of its customer base, marketing and customer support. In addition, the MNO could incur additional costs associated with buying QoE data for improving its network operation from the OTT provider.

  Regarding revenue streams, in addition to the traditional OTT provider's revenue streams (e.g., subscription fees, advertisement), the OTT provider could sell QoE data to those MNOs interested in improving the network performance. Other revenue sources would come from the offer of QoE-based differentiated services and the categorisation of customers based on interests and profiles. QoE data may also be

sold to other companies interested in getting a closer understanding of users' profiles to reach them with commercial products and services.

Table 2 Comparison of considered scenarios

	MNO	*OTT*
Scenario 1 (lead by MNO strict NN)	QoE incorporation limited to monitoring. Revenues from traditional services (i.e., mobile broadband services, IoT, etc.) but with higher level of personalisation in the commercial offer since technical mechanisms cannot be fully deployed due to the regulatory restrictions. QoE data might impact marketing offers no technical operation.	Revenues from content/application provision. Indirect benefits of MNO improvements.
Scenario 2 (lead by OTT strict NN)	Business model limited to the connectivity service provision. MNO with reduced power acting as a 'dumb pipe'. QoE does not impact MNO technical operation.	QoE incorporation by monitoring. OTT provider generates revenues from highly personalised/customised content/application provision.
Scenario 3 (lead by MNO liberal NN)	QoE incorporation monitoring/service operation. MNO with leading role in the value network. (Traffic management/prioritisation). Revenues from QoE-differentiated services/paid prioritisation and QoE data selling.	Revenues from content/application provision. QoE data might impact service provision/marketing offers. It benefits from network operation improvements. New service offer based on paid prioritisation alliances with MNO.
Scenario 4 (lead by OTT liberal NN)	More balanced correlation of forces MNO/OTT. Revenues from QoE differentiated services/paid prioritisation.	QoE incorporation by monitoring/service provision. OTT provider closer to the end-user. QoE data might impact service provision/marketing offers. New service offer based on paid prioritisation alliances with MNO.

Meanwhile, the MNO would continue earning revenues attached to subscription fees. In scenario 4, MNOs could obtain new revenues by charging for the prioritisation of content. It might be possible to generate revenues by charging fees for ads in content or from the content/service provider to guarantee users' access to their services even when 'there are no bits in the bucket' or zero-rating. However, this case needs to be studied in light of the regulatory framework.

5.5 Discussion on considered scenarios

The effect of the incorporation of QoE feedback in mobile networks by implementing the mechanism described in Section 4 has been illustrated using the scenario planning process and VNC analysis. Obtained results can be used as a reference when implementing systems to incorporate QoE feedback in the mobile network to identify limitations, required features and alternatives in each one of the proposed scenarios. A comparison of scenarios and the impact on the MNO and OTT provider is summarised in Table 2.

Although studies like those carried out by Aznar et al. (2011), Perkis et al. (2014) and Stojanovic et al. (2015) have highlighted some of the business implications of using QoE in the mobile networks, they have not covered an understanding of the regulatory framework and its implications on both the implementation of technical mechanism for QoE incorporation in mobile networks and the potential business alternatives.

Our analysis is based on interviews with major ecosystem stakeholders and indicates that incorporating and commercially exploiting QoE in mobile networks is highly impacted by the regulatory framework. This framework limits what mechanisms and techniques can be used. Conversely, the analysis presented in this paper can be the starting point of research work focused on definition of appropriate SLA/ELA [as proposed by Frangoudis et al. (2014) and Varela et al. (2015)], considering the impact of regulatory conditions and the complexity of the relations between the different actors in the mobile ecosystem.

The analysis presented in this paper offers new elements and considerations based on a comparison of different scenarios, with different regulatory scenarios and key actors heading the QoE incorporation. From the point-of-view of the MNO, those scenarios, along with strong NN regulation, can be the most troublesome. The QoE incorporation scope is limited to monitoring and capturing QoE data, and, revenues are limited to the traditional service offering. Scenario 1 might limit alternatives to stand out from competitors by centring the discussion on marketing offers not on the potential for technical improvements. In this scenario, QoE leveraging centres on the market elements but not the technical operation. Business models can follow the current approach (i.e., mobile broadband services, IoT, etc.) but a with higher level of personalisation in the commercial offer since technical mechanisms cannot be fully deployed due to the regulatory restrictions.

Scenario 2 reduces the power of MNOs, leaving them with the role of a dumb pipeline, and the OTT provider strengthens their position by getting closer to the users' needs and requirements.

Meanwhile, scenarios 3 and 4 offer the best opportunities to exploit the entire potential of QoE incorporation. Scenario 3 offers the MNO the opportunity to consolidate its position within the ecosystem, as the QoE incorporation scope is extended to include both monitoring and quality provision, which means that QoE data can be used in the implementation of traffic management/prioritisation techniques with a clear business goal. In this scenario, MNO can generate new revenue streams by offering QoE-based differentiated services and by prioritising content according to commercial interests and alliances with OTT providers. Selling information to OTT providers can also be a revenue source for MNOs.

Scenario 4 offers a more balanced correlation of forces between MNO and OTT and allows the creation of new business models based on QoE differentiation. However, the OTT controlling of users' QoE feedback can have a negotiation element when discussing potential alliances with MNOs, as an MNO interested in improving network performance and/or implementing traffic management/prioritisation may need to buy QoE data from the OTT provider.

For OTT providers in general, those scenarios in which the QoE incorporation is led by an MNO might represent a challenge. Scenario 1, in which QoE incorporation is implemented by an MNO under strong regulation, seems to be less risky in terms of revenues for OTT providers. Even though an MNO can have closer access to users' feedback and improve network operation, one of the main beneficiaries of the network

performance improvements are the OTT providers, as Scenarios 2 and 4 offer the OTT provider the opportunity to get more in touch with users and their feedback. OTT providers can, in both cases, use obtained feedback to improve service provision and the use of network resources.

In scenario 2, the incorporation of QoE is limited to monitoring functions, while, in scenario 4, the monitoring function feeds the quality provision role of OTT provider. Scenario 2, because of regulatory restrictions, might limit the impact of the improvements due to the control of network resources by the MNO and the limitations with the implementation of paid prioritisation schemes. Scenario 4 makes it possible to establish commercial alliances with MNOs while taking advantage of the intelligence provided by QoE data to activate new service offers that fit with the MNO and the OTT provider goals. In both scenarios, by incorporating QoE, it might be possible to create new revenue streams for OTT providers. Regarding scenario 3, the OTT provider might see their influence in the ecosystem reduced due to increase in the control capacity by the MNO. Alliances and commercial strategies can be alternatives to maintain an active role in the ecosystem. From the users' perspective, scenarios 3 and 4 might extend the offer of services, increasing the personalisation of services and QoE-based differentiation with technical features implemented to achieve or satisfy users' demands.

6 Conclusions

In this paper, we aim to uncover how mobile operators can incorporate QoE feedback to improve their service offer considering technical and business implications. Increased level of QoE from MNOs and OTT service providers is recognised as strategies towards increasing customer retention and reducing falling revenues from SMS and other telco-based services.

Through the use of a scenario planning method combined with VNC and business model analysis, we examine the implications of increased incorporation of QoE in services from the perspectives of MNO and OTT providers. Our approach adopts the technical mechanism devised to incorporate QoE in mobile networks while evaluating how the regulatory framework might affect the implementation of the technical mechanism by either the MNO or the OTT provider. This research approach is novel compared to previous research findings, like those carried out by Aznar et al. (2011), Perkis et al. (2014) and Stojanovic et al. (2015).

Based on interviews with major ecosystem stakeholders, we constructed four scenarios to evaluate implications of using QoE as a basis of the mobile network operation. The analysis shows that value-added offer, QoE differentiation and personalisation of services can be seen as advantageous alternatives to generate new revenue streams for telecom actors in the mobile network market. However, strict NN regulation sets limits to what techniques can be employed to implement business models based on incorporating QoE feedback in mobile networks. Services can be differentiated but from a pure marketing perspective without involving technical features.

For both MNO and OTT, the scenarios with a liberal approach on NN rules might open the door for new business models based on QoE differentiation. Revenues can come from the implementation of paid-prioritisation agreements between the OTT and the MNO, the offer of specialised services with the creation of different service/user

categories or paid access to customers' feedback regarding content/services that can be used to improve service offers. Independent of the regulatory framework, the incorporation of QoE feedback can impact the power balance in a mobile network's ecosystem. The actor leading the QoE incorporation will have access to a richer knowledge of users' interests and expectations. This information combined with a deeper understanding of network performance will make it possible to define and realise value propositions based on a particular customer's interests. In addition, QoE-based information is a valuable resource that becomes a negotiation tool when establishing commercial alliances with a counterpart. These benefits can be extended within a liberal regulatory approach on NN, allowing the MNO to offer personalised/prioritised contents to its customers while also charging OTT providers for fast-lanes access, opening the door for new business models.

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