OTT-ISP Joint Service Management: A Customer Lifetime Value Based Approach

Arslan Ahmad, Alessandro Floris, and Luigi Atzori
DIEE, University of Cagliari, Italy
{*arslan.ahmad, alessandro.floris*}*@diee.unica.it, l.atzori@ieee.org*

***Abstract*—In this work, we propose a QoE-aware collaboration approach between Over-The-Top providers (OTT) and Internet Service Providers (ISP) based on the maximization of the profit by considering the user churn of Most Profitable Customers (MPCs), which are classified in terms of the Customer Lifetime Value (CLV). The contribution of this work is multifold. Firstly, we investigate the different perspectives of ISPs and OTTs regarding QoE management and why they should collaborate. Secondly, we investigate the current ongoing collaboration scenarios in the multimedia industry. Thirdly, we propose the QoE-aware collaboration framework based on the CLV, which includes the interfaces for information sharing between OTTs and ISPs and the use of Content Delivery Networks (CDN) and surrogate servers. Finally, we provide simulation results aiming at demonstrating the higher profit is achieved when collaboration is introduced, by engaging more MPCs with respect to current solutions.**

***Index Terms*—Quality of Experience (QoE), Over-The-Top (OTT) service, Internet Service Provider (ISP), Customer Lifetime Value (CLV).**

I. Introduction

The recent developments in the multimedia industry, especially Over-The-Top services (OTTs) such as YouTube, Netflix, Skype, Facebook, have changed the Internet traffic to multimedia traffic. Indeed, with the recent findings, the Internet traffic is predicted to be 75% multimedia traffic by 2020 [1]. Such a drastic increase of multimedia traffic requires Internet Service Providers (ISPs) to upgrade their networks to deal with issues regarding the quality delivered to end users because most of the time this is degraded due to bottlenecks in the ISPs' networks. Moreover, within the multimedia service delivery chain, ISPs are the most affected entities by the user churn because most of the users switch their Internet connection to another ISP. Consequently, this leads to decrease in market share and reputation as well as lower revenue for an ISP.

Since Quality of Service (QoS) is a system centered measure of service quality, in the last decade the research has been shifted to Quality of Experience (QoE), which is a function of QoS but reflects the quality as perceived by the user. Indeed, the recent research reveals QoE as a multidimensional metric based on several influencing factors such as human, economic, network, application and context [2]. Subsequently, this shift of research paradigm towards QoE is leading to a big change in network monitoring, modeling and management techniques from Key Performance Indicators (KPIs) to Key Quality Indicators (KQIs) [3], [4]. However, although network and application providers share the common objective of providing better service quality to their customers, to date research in this field is divided into two separate paths: on the one hand network-aware application management approaches adapt application parameters on the basis of the monitored network status; on the other hand, application-aware network management approaches adapt network resources on the basis of the services to be delivered through the network. Delivering adequate QoE to their customers has become fundamental for network and application providers in order to decrease the user churn and consequently increase their profits. For this reason, in our previous work, we investigated the implementation of a QoE centered collaboration approach, between OTT and ISP, driven by revenue maximization [5].

The major contribution of this paper is multifold. Firstly, we investigate the different perspectives of ISP and OTT regarding QoE management and why they should collaborate. We focus on quality delivery and technical reasons as well as economic reasons. Secondly, we provide some examples of ongoing collaborations in the industry regarding multimedia service delivery. Thirdly, we propose a QoE-aware collaboration approach between OTT and ISP based on the maximization of the profit by considering the user churn of Most Profitable Customers (MPCs), which are classified in terms of the Customer Lifetime Value (CLV). We define the technical aspects of the collaboration, i.e., the interfaces for the information exchange between OTT and ISP and the possible solutions for a QoE-aware management of network and applications such as the utilization of Content Delivery Networks (CDN), surrogate servers, best path routing, etc. Finally, we provide simulation results aiming at demonstrating the higher profit achieved by proposed collaboration approach with respect to current solutions.

The paper is organized as follows. In Section II, we highlight the different perspectives of ISP and OTT with regard to QoE management. Section III presents the economic reasons which drive the collaboration approach. Section IV discusses the current ongoing collaborations between OTTs and ISPs for multimedia service delivery. In Section V we present our proposed collaboration approach whereas Section VI presents

The work on this paper was funded from the European Unions Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant agreement No 643072, Network QoE-Net (http://qoenet-itn.eu).

simulation results. Finally, Section VII concludes the paper.

II. Why is the collaboration needed: different perspectives of OTT and ISP

ISP and OTT have different perspectives with regard to QoE management, which are mainly influenced by their roles in the service delivery chain. The ISP is the owner of the network through which its customers are allowed to connect to the Internet as well as to subscribe to OTT services. Nowadays, users are more quality demanding and the ISP has the difficult role in managing the enormous amount of traffic generated by OTT services (especially multimedia services) to provide adequate QoE to the users. Though, the ISP has a network centered view of the quality provided and manages the network on the basis of QoE predictions provided by QoS-to-QoE models in function of monitored KPIs, i.e,

$$QoE^{ISP} = f_1(KPI_1, \cdots, KPI_i, \cdots, KPI_I), \quad (1)$$

which means that the QoE predicted by the ISP is a function of I network KPIs. Examples of QoE-based network management approaches are provided in [6], [7]. However, the QoE predicted with Eq. (1) does not represent the actual quality perceived by the users. The main reason is that the ISP does not have direct access to users' devices nor application information can be acquired by inspecting network traffic due to the data encryption by the OTTs. Even if the Deep Packet Inspection (DPI) works for some of the OTT services, the human and context influence factors will be still missing and more complex context-aware QoE models for specific applications cannot be integrated into the service delivery [8].

On the other hand, the OTT has access to some types of user-related information (e.g., application usage, preferred application settings, etc.) having its application running on the users' devices. Although the users' needs and expectations are known to OTT, it is limited in providing a good QoE to the users because most of the issues occur in the network and the OTT has no control over the network. The only optimization of the quality which OTT can perform is the adaptation of service parameters in function of the available network conditions in order to maximize the QoE, i.e.,

$$QoE^{OTT} = f_2(KQI_1, \cdots, KQI_j, \cdots, KQI_J, /QoS), \quad (2)$$

which means that the QoE predicted by the OTT is a function of J KQIs which in turn depend on the network QoS. Hence, the optimization on the OTT side is done on the basis of application quality indicators only. Examples of QoE-based application management approaches are rate adaption algorithms for HTTP Adaptive Streaming (HAS) [9].

From Eqs. (1) and (2), it is clear that not only the OTT and ISP have different perspectives in terms of QoE measurements but they also have different roles in the management and optimization of the delivered quality. However, optimal end-to-end QoE-based service delivery can only be possible if OTT and ISP collaborate and agree upon a common QoE-based management approach and exchange of the QoE-oriented information. Since the OTT is more QoE-oriented, its role in the collaboration may be the monitoring of the QoE perceived by the users. By sharing this information with the ISP, this may be able to manage the network in a more QoE fashion than by using QoS-to-QoE models. By following a joint service management paradigm, both the entities may overtake their limitations in QoE management: the ISP can manage its network in a QoE fashion and the OTT can base on the ISP if better network resources are needed for service delivery.

III. Economic View

It is a matter of fact that the proper management of QoE brings to direct economic advantages; in fact, if a customer does not receive adequate QoE, it is more likely to become a churner. Indeed, survey results showed that around 82% of customer defections are due to frustration over the service and inability of the operator to deal with this effectively [10]. Moreover, frustrated customers will tell other people about their bad experiences, resulting in negative publicity for the provider. It is also important to note that most of the customers do not complain before defecting but they simply leave once they become unsatisfied. Therefore, it is very important that providers investigate user's expectations and constantly monitor delivered quality to prevent the user churn. From another survey, 20% of respondents reported that they would immediately leave a company because of poor service experience [11]. But most importantly, it resulted that the number of customers who leave because of poor customer experience is significantly higher than the number of those who leave a business because they found a lower price elsewhere: 68% versus 53%. For this specific case, service quality has more influence on the user churn than price.

Therefore, delivering good QoE may help to contrast the user churn and increase the revenue. Usually, the most used parameter for revenue measurement is the Average Revenue Per User (ARPU), which is calculated as

$$ARPU = \frac{TotalRevenue}{TotalNumberOfSubscribers} \quad (3)$$

However, this metric does not explicitly represent the impact of a single user on the total revenue, it makes no consideration of the service profitability and does not consider the cost of managing the customer service within the network. Differently, for profit maximization, it is important for the providers to understand the 'value' of each customer in terms of profit, i.e., the revenue (price paid by the customer for the services received) minus the costs (costs for providing the services and managing the customer). Indeed, for the providers, some customers have more value than others and the identification of these customers allows the operator to drive retention actions to the most profitable customers.

Therefore, we consider the Customer Lifetime Value (CLV) as the metric for customer selection because it is defined as "the total value of direct contributions and indirect contributions to overhead and profit of an individual customer during the entire customer life cycle, from the start of the relationship to its projected ending" [12]. CLV is basically computed as

$$\begin{aligned} CLV = (TotalCustomerRevenue) \times \\ (NumberOfLoyalYears) \times \\ (CompanyProfitMargin) \end{aligned} \tag{4}$$

Several modified versions of CLV formula are provided in the literature. For example, in [13] the CLV of the customer i, for the horizon h from the period t is defined as

$$CLV_{i,t} = \sum_{k=1}^{h} \sum_{j=1}^{q} \frac{\pi_j x_{i,j,t+k}}{(1+r)^k} \tag{5}$$

where r is the discount rate and the net cash flow yielded by the transaction on product j is computed as the product of the product usage $x_{i,j,t}$ and π_j, i.e., the marginal profit by a unit of product usage. This is a marketing equation for a general product but it may be used, for example, for computing the CLV of the customers of call services, for which the profit depends on the service usage. However, this equation cannot be applied in the case of flat rates because of the pricing structure that charges a single fixed fee for a service, regardless of usage. Since flat rates are common in telecommunication and multimedia services, we provide a CLV equation for this pricing strategy as follows

$$CLV_{i,t} = \sum_{k=1}^{h} \sum_{l=1}^{L} \frac{\pi_l s_{i,l,t+k}}{(1+r)^k} \tag{6}$$

where l is the level at which a service s is provided and the marginal profit π_l depends on the level l. Indeed, generally, more than one fixed fee can be chosen by the customers, which depends on the level of usage of the service they need. If this level is overtaken, additional fees are applied.

Only the customers which have already been acquired are involved in churn modeling and the CLV helps to identify these customers. One of the major objectives of ISP and OTT is to maximize their profit and to do this we focus on minimizing the churners.

IV. Current Trends in Multimedia Industry

The Internet service delivery chain involves several entities including ISPs, regional/global transit providers, OTTs, Content Delivery Networks (CDNs) and Internet eXchange Points (IXPs). The role of each entity is different and services are delivered based on mutual agreements [14]. Currently, in the multimedia industry collaboration agreements are QoS-based and the most common form of collaborations between OTTs and ISPs can be classified into two categories: peering and surrogate servers. The rest of this section briefly highlights some of the ongoing practices used in the multimedia industry for the delivery of quality to the end users.

A. Peering

Currently, most of OTT services use different CDNs for the decentralization of the contents so that these are located near to the users on a regional basis in order to lower the content retrieval latency. A recent form of collaboration between OTT and ISP can be seen as the ISPs peering with the CDNs of the OTTs. On the basis of peering policies, peering agreements between OTT and ISP can be classified as Settlement-Free-Interconnection (SFI) and Paid-peering. The former is the mostly used peering strategy found in the industry while the latter is considered as a violation of Network Neutrality [14]. Technically, the peering can be categorized as 1) Direct or Private Network Interconnection (PNI) and; 2) Public Peering Interconnection (PPI) through the IXPs. To understand the usage of these options, we analyze the cases of YouTube (Google), Skype (Microsoft) and Netflix as some of the popular OTT services.

YouTube video streaming is mostly delivered by Google CDNs where the CDNs are connected to the Google core data centers [15]. Google provides both PNIs and IXPs based peering to ISPs based on SFI peering policy with two different Google Autonomous Systems (ASs), which provide a complete set of Google services (common peering option) and a subset of Google's most popular content (available at a small number of locations) [15]. Similarly, for Skype, Microsoft is providing SFI based PNIs and IXPs peering connections where the peer should declare all the routing paths and Microsoft carries traffic optimization for the Skype generated traffic on the basis of network latency [16]. In the case of Netflix, there are several SFI based open peering PNIs and IXPs connections for the ISPs; however ISP ready for the peering agreement needs to join Netflix Open Connect Program, whose purpose of peering is not only to provide better connection between Netflix's CDN and ISP but also to move the most popular content near to end users inside the host's network with Netflix's surrogate servers called Embedded Open Connect Appliances (OCAs) [17].

B. Surrogate servers

It is also found to be a normal ongoing practice by the OTTs to provide the hosting ISP with surrogate servers, which can be installed inside the host network to provide the contents near to the end users. The selection of the content is based on the usage trends which are known to the OTT. The surrogate servers provide mutual benefits for the two providers: by decreasing the transit requests, the ISP decreases transit costs as well as the network overload in the backbone network; furthermore, it allows to deliver the OTT contents with less latency than just a simple peering. Most of the surrogate servers based collaborations found in the industry are settlement-free where none of the parties pay each other but they agree on mutual benefits. An important case is the one of Google that is providing Google Global Cache (GGC) edge nodes to ISPs with more Google's applications (YouTube, Google Play, Google Search, Google Maps etc.), which are capable of treating from 60% to 80% of the traffic generated by Google's application [15]. Another is the case of Microsoft that is providing surrogate servers to ISPs for Skype services [16], whereas Netflix is providing the collaborating

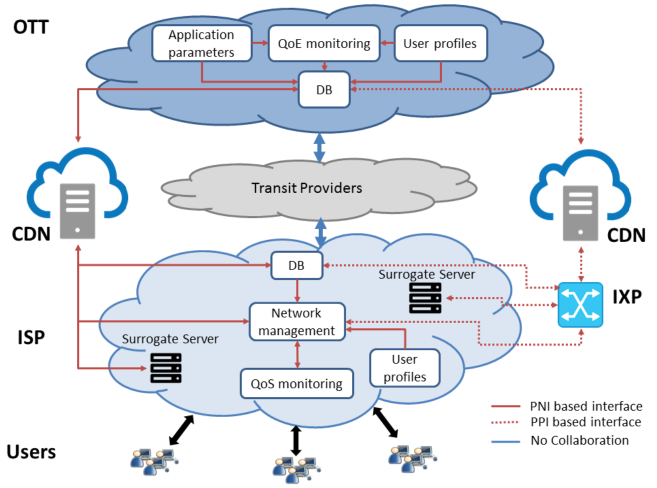

Fig. 1. Reference architecture for the proposed OTT-ISP collaboration approach.

ISPs with OCAs surrogate servers under Netflix Open Connect program [17].

V. Proposed Collaboration Approach

As analyzed in the previous sections, OTTs and ISPs are collaborating on a QoS basis through peering and surrogate servers to deliver better service quality rather than considering the user perceived quality. To address this limit, we propose a QoE-aware collaboration approach where optimization on both network and application sides is done jointly on the basis of economic factors expressed in terms of the Customer Lifetime Value (CLV), as highlighted in Section III. The proposed collaboration approach is inspired by the settlement-free peering policy where none of the partner organizations pay each other. The main reason is that the collaboration with the OTT may reduce the transit costs for the ISP; indeed, if contents are provided by CDNs and surrogate servers, the ISP does not have to pay transit providers. Moreover, the collaboration with the ISP may decrease the user churn for OTTs because thanks to the information provided by the OTT, the ISP can deliver multimedia services with better QoE. As demonstrated in [5], the higher the QoE the lower the user churn and the higher the profit for OTT and ISP. Therefore, the collaboration brings advantages to both the parties.

The reference architecture of the proposed collaboration approach is illustrated in Fig. 1. The OTT monitors the QoE of the users as a function of application and network parameters and customer profiles using specific QoE models for the delivered services. A survey on parametric QoE estimation models for popular services is provided in [18]. The QoE is measured per user session each time the user utilizes the application. The measured QoE is stored in the OTT database together with the type of application and the IP address and CLV of the customer. Similarly, the ISP has its own database in which the IP address and the CLV of each customer are recorded. IP and CLV values are updated only if they change. The OTT provides the ISP with APIs which allow the ISP to get all the OTT information from the OTT database. As highlighted in Fig. 1, information exchange between OTT and ISP can occur through both PNI based interface (information is directly shared by PNI peering interfaces via OTT's CDN) and PPI-based interface (peering and exchange of information is done through publicly available IXPs, e.g., PeeringDB [1]).

On the basis of the IP addresses, the ISP creates a table composed of the customers in common between the ISP and the OTT. These customers are then sorted in function of their CLV. Specifically, the CLV considered is the sum of the CLV computed by the OTT with the CLV computed by the ISP so that, for a customer i:

$$CLV_i^{TOT} = CLV_i^{OTT} + CLV_i^{ISP} \qquad (7)$$

The higher the CLV_i^{TOT}, the most profitable is the customer for both the ISP and the OTT. Note that the OTT may just provide normalized CLV data not to disclose the real absolute values to the external world still allowing the collaboration to work properly.

Getting customers' information from the OTT, the ISP has a total overview of common customers, from their network resources to their perceived QoE as well as their economic impact. The objective of the ISP-OTT collaboration is to implement a QoE-aware management of the network to minimize the user churn of customers with the highest CLV_i^{TOT} so to maximize the profit. Then, the first step is to classify customers into two classes depending on their CLV_i^{TOT}. Specifically, a threshold is chosen to distinguish between most profitable customers (MPCs) and standard customers (SCs). The threshold depends on the difference of CLV_i^{TOT} among the customers. However, since resources are limited and costly, the percentage of MPCs should not be too high. For example, a 20% or 30% could be a reasonable percentage. Though, these decisions should be evaluated case by case.

The second step is to identify, within the whole territory controlled by the ISP, the location zones (LZs) where most of the MPCs are situated. Let $n = 1, 2, \ldots, N$ indexes the LZs controlled by the ISP. These LZs are ranked on the basis of the number of MPCs belonging to each of them. Following this ranking, more network and application resources are provided to the highest ranked LZs to optimize QoE of these customers and lose as few MPCs as possible.

Since the focus is on multimedia services, for QoE optimization several actions may be possible, such as i) network management implemented by the ISP for traffic prioritization on the basis of the type of service to be delivered [6]; ii) the places where surrogate servers should be located must be as close as possible to the highest ranked LZs; iii) the contents replicated on the surrogate servers must be the most viewed by MPCs. Indeed, as discussed in [19], CDN basically deals with the issues of identifying where to place surrogate servers and identifying what content to replicate on the servers. With the proposed collaboration approach, these issues are

[1] https://www.peeringdb.com/

solved with a major focus on profit maximization. In fact, if surrogate servers will be situated closer to the highest ranked LZs, customers belonging to these LZs will perceive better QoE due to the improvement of service delivery.

VI. Simulation and Results

The objective of the simulations is the evaluation of the potentialities of the collaboration approach proposed in Section V in comparison with the No collaboration in terms of the QoE delivered and the user churn for MPCs and SCs. As a use case, we focus on video streaming services which are currently the most popular and resource consuming services. Therefore, the considered scenario consists in an ISP and a video streaming service (OTT), which collaborate with the aim to increase the profit. The ISP's network covers a certain region divided in different LZs, and the objective is to provide better resources to the LZs where most of MPCs are located.

For the simulation purposes, two cases are considered, i.e., No Collaboration (NC) and Collaboration (Col): with the former approach, services are provided to all users in all LZs over the best effort Internet, while the latter is based on our proposed approach, i.e., the surrogate servers (SRs) are distributed closer to the LZs on the basis of the number of MPCs for both OTT and ISP per LZ.

The simulations are performed using the MATLAB software platform. We consider 5 different LZs in the ISP network through which the users are connected to Internet to use OTT video streaming service. The number of users for each LZ is as follows: 600 for LZ_1, 980 for LZ_2, 922 for LZ_3, 950 for LZ_4 and 896 for LZ_5. The assigned CLV_i^{TOT} to each user is randomly distributed on the normalized scale from 0 to 1: the users with the CLV_i^{TOT} greater than 0.8 are classified as MPCs whereas the others as SCs.

For prediction of the QoE, in terms of the Mean Opinion Score (MOS), the model proposed in [20] is chosen because it is designed for the HTTP video streaming:

$$MOS = \alpha \cdot e^{-\beta(L)\cdot N} + \gamma \tag{8}$$

where L and N are stalling duration and number of the stalling events, respectively, while α, γ and $\beta(L)$ are some formula parameters that have been set as follows: $\alpha = 3.5$, $\gamma = 1.5$ and $\beta(L) = 0.15 \cdot L + 0.19$.

Table I shows the KQIs, N and L, which are assumed to be provided considering different number of SRs (from 0 to 3) situated closer to a LZ. As discussed in [19], SRs contain replicas of video segments and not the whole videos. Accordingly, the customer's video client can select the SR which provides each video segment with best performance. Therefore, the higher the number of SRs closer to a LZ, the better the performance provided to the video streaming customers (both MPCs and SCs) belonging to that LZ. The values of L and N are chosen on the basis of the influence they have on the perceived QoE [20]. The difference of values between NC and Col approaches for the case of 0 SRs is due to the fact that with the Col approach the latency for the content retrieval is lower because of peering provided by CDN.

TABLE I
KQIs assumed to be provided with regard to the number of SRs for LZ for Col and NC approaches.

Approach	Number of SRs	L (s)	N
NC	0	0–4	1–5
Col	0	0–2	1–3
	1	0–1.5	1–2
	2	0–1	1
	3	0-0.5	0

Moreover, we consider the user churn function proposed in our past work [5] for the calculation of the user churn:

$$U_i(QoE_i) = \frac{1}{1 + e^{-z(QoE_i - QoE_i^m)}} \tag{9}$$

where $i = \{MPC, SC\}$ identifies the CLV class, $U_i(QoE_i)$ is the user churn of the user belonging to i-th CLV class, QoE_i is the mean quality delivered over the time period of a month, and QoE_i^m is the quality level at which 50% of the users leave the service. Moreover, z is the sensitivity of human perception to the perceived quality. The QoE_i^m in Eq. (9) is set to 3 and 2.5 for the MPCs and SCs users respectively while $z = 3.5$ for both. The user churn is calculated using mean of 100 iterations of the QoE delivered per LZ over a month.

We considered the distribution of 5 SRs to the 5 LZs. Fig. 2 shows how the number of SRs per LZ influences the user churn of MPCs and SCs, respectively. It is evident that the higher the number of SRs, the higher the QoE perceived by the customers and the lower is the user churn. However, 2 SRs are more than enough to provide a satisfying level of QoE because customers are not leaving the service. It is important to note that we are not considering new customers joining the services but only the number of customers leaving the service with respect to customers present at the time of service's activation.

We considered 4 different distributions for simulations and the results are shown in Table II. The best results are obtained with the distribution D_3, which allows to lose the lower number of MPCs and SCs. However, with respect to the NC approach, all the distributions considered for the Col approach provide better results, both in terms of user churn (reduced from 95% to 16% for MPCs and from 73% to 3.71%, using D_3) and QoE (increased from 2.59 to 3.76, using D_3). Even though the D_3 is not providing the highest average QoE as compared to D_1 but the user churn is lower than the other distribution because the resources are more distributed among LZs in accordance with MPCs.

VII. Conclusion

In this work, a QoE-aware collaboration approach between OTT and ISP is proposed, based on the maximization of the profit. The objective is to improve the service delivery to the LZs with the highest number of Most Profitable Customers (MPCs) (classified in terms of the Customer Lifetime Value (CLV)) by distributing Surrogate Servers (SRs) closer to these LZs. With simulation results we show that with the proposed collaboration approach the user churn of MPCs and SCs is reduced respectively from 95% to 16% and from 73% to

TABLE II
SIMULATION RESULTS.

SR distribution	LZ ranks					N. of leaving MPCs (%)	N. of leaving SCs (%)	Average QoE
	$1(LZ_5)$	$2(LZ_3)$	$3(LZ_4)$	$4(LZ_1)$	$5(LZ_2)$			
N. of SRs per LZ (D_1)	3	2	0	0	0	24.73	6.89	**3.86**
N. of SRs per LZ (D_2)	2	2	1	0	0	18.61	4.89	3.77
N. of SRs per LZ (D_3)	2	1	1	1	0	**16.37**	**3.71**	3.76
N. of SRs per LZ (D_4)	1	1	1	1	1	20.97	4.34	3.69
N. of SRs per LZ (NC)	0	0	0	0	0	95.05	73.48	2.59

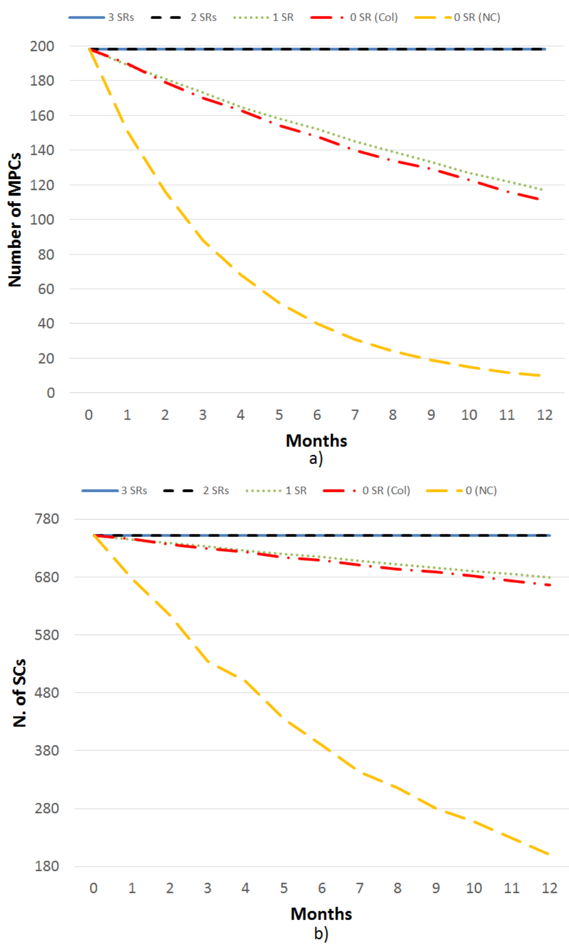

Fig. 2. Number of MPCs (a) and SCs (b) leaving the service as a function of the number of SRs closer to their LZ.

3.71%. This is due to the better QoE perceived by these customers, which is increased (in terms of MOS) from 2.59 for no collaboration to 3.76 for the collaboration approach.

REFERENCES

[1] "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015-2020 White Paper," 2014.

[2] P. Le Callet, S. Möller, A. Perkis *et al.*, "Qualinet White Paper on Definitions of Quality of Experience (2012)," in *European Network on Quality of Experience in Multimedia Systems and Services (COST Action IC 1003)*, Lausanne, Switzerland, Version 1.2, March 2013.

[3] S. Baraković and L. Skorin-Kapov, "Survey and Challenges of QoE Management Issues in Wireless Networks," *Journal of Computer Networks and Communications*, vol. 2013, 2013.

[4] M. Varela, P. Zwickl, P. Reichl, M. Xie, and H. Schulzrinne, "From Service Level Agreements (SLA) to Experience Level Agreements (ELA): The challenges of selling QoE to the user," in *Communication Workshop (ICCW), 2015 IEEE International Conference on*. IEEE, 2015, pp. 1741–1746.

[5] A. Ahmad, A. Floris, and L. Atzori, "QoE-centric service delivery: A collaborative approach among OTTs and ISPs," *Computer Networks*, vol. 110, pp. 168–179, 2016.

[6] J. Seppänen, M. Varela, and A. Sgora, "An autonomous QoE-driven network management framework," *Journal of Visual Communication and Image Representation*, vol. 25, no. 3, pp. 565–577, 2014.

[7] E. Liotou, D. Tsolkas, N. Passas, and L. Merakos, "Quality of Experience Management in Mobile Cellular Networks: Key Issues and Design Challenges," *IEEE Communications Magazine*, vol. 53, no. 7, pp. 145–153, 2015.

[8] T. Hoßfeld, L. Skorin-Kapov, Y. Haddad, P. Pocta, V. A. Siris, A. Zgank, and H. Melvin, "Can context monitoring improve QoE? a case study of video flash crowds in the internet of services," in *Integrated Network Management (IM), 2015 IFIP/IEEE International Symposium on*. IEEE, 2015, pp. 1274–1277.

[9] M. Seufert, S. Egger, M. Slanina, T. Zinner, T. Hoßfeld, and P. Tran-Gia, "A Survey on Quality of Experience of HTTP Adaptive Streaming," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 1, pp. 469–492, 2015.

[10] "Nokia White Paper, Quality of Experience (QoE) of mobile services: Can it be measured and improved?" http://afutt.org/Qostic/qostic1/MOB-GD-MGQ-NOKIA-040129-Nokia-whitepaper_qoe_net-final.pdf.

[11] "Customer service, not price, remains top cause of customer churn, accenture study finds, https://newsroom.accenture.com/subjects/customer-relationship-management/customer-service-not-price-remains-top-cause-customer-churn-accenture-study-finds.htm."

[12] J. C. Hoekstra and E. K. R. E. Huizingh, "The Lifetime Value Concept in Customer-Based Marketing," *Journal of Market-Focused Management*, vol. 3, no. 3, pp. 257–274, 1999.

[13] N. Glady, B. Baesens, and C. Croux, "Modeling churn using customer lifetime value," *European Journal of Operational Research*, vol. 197, no. 1, pp. 402–411, 2009.

[14] C.-L. Yeh, "Conceptualized framework for regulation of OTT video services: A new battlefield of interconnection and peering," in *20th ITS Biennial Conference, Rio de Janeiro 2014: The Net and the Internet-Emerging Markets and Policies*. International Telecommunications Society (ITS), 2014.

[15] "Google peering," (Date last accessed 28-November-2016). [Online]. Available: https://peering.google.com/

[16] "Microsoft peering," (Date last accessed 28-November-2016). [Online]. Available: https://www.microsoft.com/Peering

[17] "Netflix open connect," (Date last accessed 28-November-2016). [Online]. Available: https://openconnect.netflix.com

[18] D. Tsolkas, E. Liotou, N. Passas, and L. Merakos, "A survey on parametric QoE estimation for popular services," *Journal of Network and Computer Applications*, vol. 77, no. 1, pp. 1–17, 2017.

[19] A. Passarella, "A survey on content-centric technologies for the current Internet: CDN and P2P solutions," *Computer Communications*, vol. 35, no. 1, pp. 1–32, 2012.

[20] T. Hoßfeld, R. Schatz, E. Biersack, and L. Plissonneau, "Internet Video Delivery in YouTube: From Traffic Measurements to Quality of Experience," in *Data Traffic Monitoring and Analysis*, E. Biersack, C. Callegari, and M. Matijasevic, Eds. Springer Berlin Heidelberg, 2013, pp. 264–301.