QoE Awareness for the Mobile Termination Rates Monopoly Liberation

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Abstract—**Charging for Quality-of-Experience (QoE) is the key to overcome the monopoly of the Mobile Termination Rates (MTR) market. An Axiomatic QoE model (AQX), which considers simultaneously technical and non-technical parameters, is proposed to estimate end-user's QoE. AQX is used as a bidding metric in the Auction-based Charging User-centric System (AbaCUS). AbaCUS defines the Mobile (Virtual) Network Operator (MvNO) maximizing end-user's QoE. An automatic and on-demand MvNO selection mechanism is then used to register end-users mobile devices in the desired MvNO. This mechanism has been implemented and evaluated in terms of its time and energy efficiency.**

1. Introduction

In mobile communication the mobile termination service involves charges between Mobile (Virtual) Network Operators (MvNOs). Furthermore, only the MvNO of the callee is able to terminate his calls. Thus, in the MvNO call-termination market there is only one player profiting from Mobile Termination Rates (MTR); in turn this market is considered by regulators to be a "de-facto" monopoly [2], since the early days of the introduction of commercial mobile communication services. Given this monopoly fact, the only solution against a potential speculation by MvNOs was the regulation of MTR [4] [6] [8].

In a monopoly there is a corporation that is the only seller of a good or a service, and thus it can define the price. However, monopolies can be divided into two categories, the naturally defined and the market-defined monopolies. The power market in many countries is considered to be a natural monopoly, and the main reason is that there is usually only one power-wire reaching each house. Thus, only the company that owns the delivery network can provide power services. The termination service in mobile communication until the 4G is also considered to be a monopoly. However, this is a market-defined monopoly, since there is no physical limitation (*e.g.*, wires) for reaching a mobile user.

The 2.5G and higher mobile communication technology allows for flexible charging mechanisms, such as on-demand MvNO selection combined with non-static MTR, that could overcome the MTR monopoly obstacle. Thus, this work shows that the mobile termination service is not a "de-facto" monopoly since 2.5G. To show that, the Auction-based Charging User-centric System (AbaCUS) is proposed in this work as a 2.5G and higher overlay, where MvNOs will participate in an auction to allow competition that aims to increase end-users Quality-of-Experience (QoE). MvNOs will charge for QoE while bidding on economic variables, such as MTR per Quality-of-Service (QoS) variables, such as the sound quality during a call and network-access guarantees, in a manner that the MvNO which will increase end-users QoE will be the one selected by an Auction Authority (Au^2) to provide the termination service.

This work is arguing that charging for QoE is the key to overcome the monopoly of the MTR market. An Axiomatic QoE model (AQX), which considers simultaneously technical and non-technical parameters, is designed in this work, to estimate end-user's QoE for a certain service (*e.g.*, the mobile termination service). Such service can be provided by competing MvNOs that can use QoE as the AbaCUS auction bidding metric defining which MvNO will provide the termination service. AQX is a generic, since it is not service-specific, QoE model that can be applied in multiple domains.

This work proposes and implements prototypically the technical mechanism needed to break the mobile termination service monopoly, an automatic and on-demand MvNO selection mechanism, and evaluates this mechanism in terms of time and energy efficiency, showing that the proposed solution is technically feasible [26].

The remainder of this paper is structured as follows. Related work is discussed in Section 2, followed by the AbaCUS architecture in Section 3. The Axiomatic QoE model is presented in Section 4, the automatic and on-demand MNO switching mechanism is presented in Section 5. Finally, Section 6 draws conclusions.

2. Related Work

The QoE concept is relatively young, but there is significant work already done in this domain [7] [21] [22] [23]. There were even some attempts to charge for QoE in real life [19]. However, there is not available so far a generic enough QoE model that can encapsulates economic and technical parameters, such as it can be used to charge for QoE in the telecommunication domain. Furthermore, a concrete scenario where charging for QoE can be applied in telecommunication is missing from the literature.

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2.1. QoE

QoE is a user-centric and service-specific concept reflecting the end-user satisfaction of a service while considering various technical variables, such as latency, bandwidth, or jitter, in VoIP services of the telecommunication field [24], or in video streaming of the entertainment field [5] [16] [33]. Furthermore, the QoE concept can also be used when considering pricing for IP-based services [14] [22] [23] [9], because the price of a service affects the overall end-user experience. Thus, QoE can be affected by (a) diverse technical variables and (b) by economical/non-technical variables.

In the Information technology (IT) ecosystem such variables are usually defined in the Service-level Agreement (SLA) between the Service Provider (SP) and its customer. When one or more of these variables do not meet the agreed level, an SLA violation is occurred. However, an SLA violation does not mean that the end-user dissatisfaction cannot be avoided.

There are certain actions that a SP can take, such as offering the service at a lower price, or offering a service upgrade, such as a higher bandwidth for the same price, to maintain the QoE of an end-user at a certain level of satisfaction. To prevent a potential decrement of QoE in case of an SLA violation, it is important to know which variables and how exactly they affect the end-user's QoE. A proper adjustment of involved variable(s) on the QoE might counterbalance the incident that caused the SLA violation in terms of the end-user satisfaction. However, such a process needs a formally complete and generic overview of the QoE concept that is missing nowadays. The need to illustrate QoE contributed to the creation of standards, such as the Mean Opinion Score (MOS) [11] [10] [12]. The MOS reflects the end-user satisfaction at a numerical scale where the higher the score is the higher the end-user's satisfaction is and vice versa. However, since the MOS defines a subjective value, a complete and formal calculation of the MOS while considering all variables that might affect the QoE is the missing piece toward the precise user satisfaction demands estimation.

2.2. MTR Monopoly

Since the early years of mobile communications, the scientific community as well as regulation authorities has invested a large effort [8] [4] [6], to reduce negative effects of the termination rates monopoly. However, the attempt to overcome negative effects of this monopoly is focused (a) on charging solutions mainly targeted at the paying party of the termination rate or (b) on regulation rules that need to be enforced by respective regulation authorities at operational MvNOs. Thus, (1) the Calling Party Pays (CPP) principle with a strong regulator presence, (2) the Receiving Party Pays (RPP) principle, and (3) a National Roaming (NatRoam) approach, aim to eliminate negative effects of the monopolistic termination rates market. However, in all cases the monopoly in this market still remains since only the MvNO of the callee can terminate his calls and profit from it.

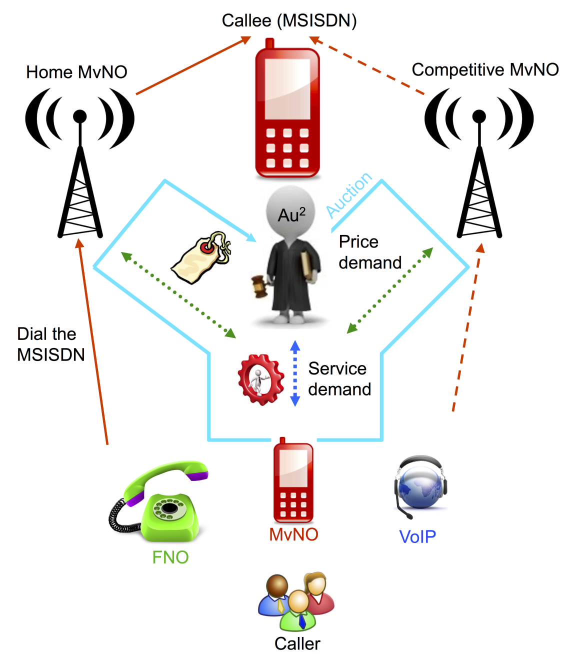

Figure 1. Key Elements of AbaCUS

3. AbaCUS

Figure 1 illustrates the key elements of AbaCUS [31]. A caller is flexible to use the voice-service provider of his choice, such as Voice over Internet Protocol (VoIP), MvNO, and Fixed Network Operator (FNO), to place a call. The caller can reach the callee by dialing directly the callee's phone number. In this case the host MvNO will collect MTR. In AbaCUS the MvNO that will maximize end-user's QoE will terminate the call and benefit from collecting MTR. The selection of the MvNO that will maximize QoE is taken via an auction that is hosted by the Auction Authority (Au^2), which is a neutral third party, such as a regulator or a Mobile Number Portability (MNP) provider [25] [15]. Alternative possibilities to an auction mechanism could be monitoring the available resources of MvNOs, and select the one with the most available resources to terminate a call. Is such case the load-distribution would be optimal. However, the end-user price influence would not be possible. Thus, in case of enough available resources there would be no benefit for end-users since the QoS variables would be equal on every MvNO selection, while QoE is influenced also by economic variables.

In AbaCUS a call can be terminated by every MvNO providing network coverage in a specific location and willing to terminate any mobile communication subscriber's call, irrespective of the provider the callee belongs to. Since the modern mobile terminal devices are multiband-compatible, there does not exist any technological boundary for this functionality anymore. Furthermore, no Subscriber Identity Module (SIM) change is required from the callee so there is no SIM-lock [18] interference with the AbaCUS call-termination MvNO-independent system. Similarly to roaming users, who can use the same device for domestic as well as abroad usage without replacing their SIM card, in AbaCUS the callee can receive a call by any MvNO that provides network coverage in his location, without the need of additional equipment.

To facilitate that a competitive MvNO can terminate the call of a foreign callee, a virtual Mobile Subscriber Integrated Services Digital Network Number (MSISDN) will be assigned to the callee once the callee's User Equipment (UE) is parked in the new network. The caller will dial the virtual MSISDN to reach the callee. In that case the guest MvNO will profit from collecting MTR. Thus, in AbaCUS multiple MvNO can participate in an auction, where a caller will request to place a call to reach a callee in a specific location while stating to the Au^2 certain technical and economic preferences (*e.g.*, sound quality and guaranteed network access) for the specific call.

4. AQX

AQX [32] [29] [30] assumes the following key QoE parameters, which are (a) service-specific, (b) user-centric, and (c) can be influenced by the Service Provider (SP) to formalize QoE.

Thus, below are summarized the axioms of the AQX model that serve as a starting point of reasoning, to be accepted as true without controversy [3].

1) To predict/estimate QoE, the first action needed is to identify all variables that affect QoE and can be measured, or can be estimated.
2) There are two types of variables affecting QoE: (a) Isotonic Variables (IV) which have an opposite effect in MOS and thus must be investigated separately. The more you have the better it is (*e.g.*, bandwidth). (b) Antitonic Variables (AV). The more you have the worst it is (*e.g.*, price).
3) For each service there are two values per variable that define (a) the worst, and (b) the best possible values.
4) For each service and end-user there is an ideal/ desired/expected/agreed value of each variable (x_0) that shows that the end-user is satisfied. This value is between the best and the worst variable values. However, in some cases the end-user can be satisfied even more, such as when receiving further price discount.
5) The fluctuation of the value of each variable might affect differently each end-user at a given service. The QoE effect of the fluctuation is expressed via the influence factor of a variable. The influence factor (m) can be different for values below and above the expected MOS (m^-,m^+).
6) Each variable affecting QoE can have different importance (w).

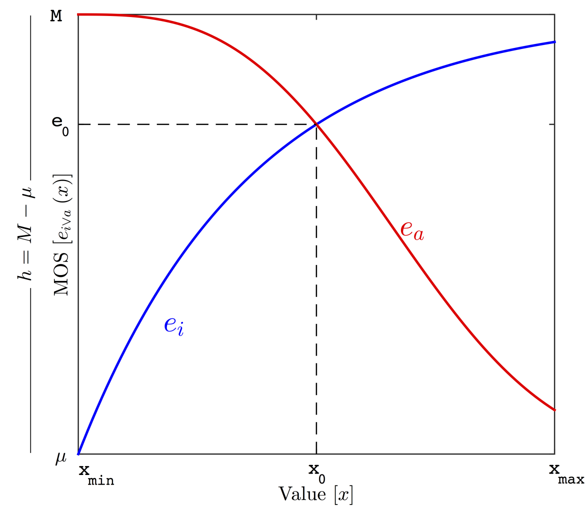

Figure 2. MOS Evolution for IV (e_i) and AV (e_a)

$$e_a(x) = h \cdot e^{-\left(\frac{x}{x_0}\right)^m \cdot \ln\left(\frac{h}{e_0-\mu}\right)} + \mu \quad (1)$$

$$e_i(x) = h \cdot \left(1 - e^{-\left(\frac{x}{x_0}\right)^m \cdot \ln\left(\frac{h}{h-e_0+\mu}\right)}\right) + \mu \quad (2)$$

$$E(X) := \mu + h \cdot \prod_{k=1}^{N} \left[\frac{e_{(i \vee a)}(x_k) - \mu}{h}\right]^{w_k} \quad (3)$$

A precise QoE formalization demands a mathematical model that is able to consider multiple and diverse variables, such as network access guarantees, network access priority, price, and bandwidth that can affect the end-user QoE positively or negatively on a given situation. Furthermore, each variable might affect QoE in a different way in each scenario. Additionally, QoE strongly depends on the end-user since each person might have different demands and priorities concerning the same services. Although a given end-user's mood at a certain time can be considered as a variable that affects QoE [20], it is not possible to be influenced by a SP. AQX is designed to model QoE that can be influenced by variables that are within SP influence-zone, such as technical and economic variables.

Equation 1 and Equation 2 are proposed in AQX to calculate QoE of a service for a given variable AV and IV respectively. To combine the MOS of multiple diverse variables AQX proposes a multiplicative approach (cf. Equation 3) to avoid domination of well-performing variables in the overall MOS.

Figure 2 illustrates QoE of the end-user for variables that can influence QoE positively or negatively when fluctuating. The Y-axis shows the MOS of a variable in the interval h and the X-axis the normalized value x of each variable. The value e_0 on the Y-axis is the expected MOS (eMOS) that corresponds to the expected, agreed, or defined in the SLA value x_0 of each variable. Thus, let e_0 be the eMOS and x_0 the Expected Variable's Value (Ev[2]). On one hand, the e_i curve reflects the MOS of a variable, such as bandwidth. Such variables while increasing to a maximum value x_{max}, imply a QoE increment to the maximum MOS value M. Those variables in AQX are termed Isotonic Variables (IV). Furthermore, when the value of an IV is minimum x_{min}, the MOS value is also minimum (μ). On the other hand, the e_a curve reflects the MOS of a variable, such as the price of a service. Such variables, contrary to IV, while increasing to a maximum value x_{max}, imply a QoE decrement to the minimum MOS μ. Those variables are termed Antitonic Variables (AV). Last but not least, when the value of a AV is x_{min} the MOS is M.

5. On-demand MNO Selection Mechanism

The end user in an Android device can select the MvNO in the network settings of the User Interface (UI). Thus, there should be a method in the Android Application Programming Interface (API) performing this action once the end-user selects from the respective menu this option. However, the public Android API does not contain any methods allowing the selection of the MvNO. However, this is possible via the internal Android API. Accessing the internal Android API requires the following steps: 1) obtain the original Android framework, 2) create a custom Android framework, 3) modify the Eclipse access rule, and 4) invoke the MvNO selection mechanism [27] [28].

5.1. Evaluation of the MvNO Selection Mechanism

Long delays are critical for services with a real-time network access, such as phone call establishment, and they may affect the end-user's QoE. Furthermore, energy is a critical resource in mobile communications. Thus, having an on-demand and automatic MvNO selection mechanism that takes a lot of time to switch between MvNO, or consumes a lot of energy, will be practically unusable. Considering that, an evaluation in respect to the time needed between MvNO switching and energy consumption has been performed.

5.1.1. Time Consumption between MvNO Switching. The switching time between MvNO might be affected by the mobility pattern of the end-user, the time of the day that the MvNO switching is being performed, and the MvNO that are involved. Thus, an experiment has been performed to evaluate the MvNO switching time and find potential correlations with the parameters mentioned above. The MvNO switching average time between the three available MvNO in Switzerland took place for the following two scenarios: (a) when the device was placed in an urban area inside a building and (b) when the device was moving on a train from Zürich to Lucerne. For a comprehensive test the switching took place between all possible MvNO pairs.

To examine, if the MvNO switching time is correlated to the time of the day, the measurements for case (a) was executed 6 times during a weekday in the following time frames (8:00, 10:30, 12:00, 14:00, 17:00, 2:00 hours). These time frames have been selected so that these measurements undertaken are spread during the day, when the network state (*e.g.*, the network load) changes between rush hours. Thus, the data of the MvNO selection consists of total 6 times 100 hops collected in different hours, concluding a total number of 3600 hops. The data of the MvNO selection for case (b) consists of a total of 100 hops per MvNO pair, reaching a total number of 600 hops, resulting in MvNO switching times as shown in Figure 3.

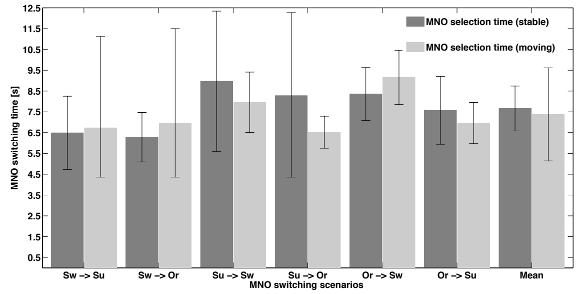

Figure 3. Switching Time Between MvNO

The first MvNO, which appears in the caption below the first set of bars, is always the MvNO, where the device was registered first, and the second MvNO is the one that has been switched to. Each bar corresponds to all switches performed, from the indicated MvNO to another. Error bars indicate the standard deviation of all measurements. However, there is a minimum time needed to complete the 6-step SIM network registration process [17]. Thus, the assumption that the minimum MvNO switching time cannot be in practice lower than the lowest value measured in this results (4.36 s) has been taken. Left bars present the average switching time between MvNO at the same location; right bars present the average switching time between the same MvNO while moving. The last set of bars presents the mean MvNO switching time for all cases (a) and (b) in summary. The large standard deviation results from large maximum values (cf. Figure 4). Due to the unstable availability of MvNO while moving on a train the maximum MvNO switching values appear to be much higher compared to the experiments at the same location is some cases. Furthermore, the MvNO selection time shows a quite unstable behavior in some of the cases, which might be related to specific MvNO's infrastructure configurations or the current capacity of the connected cell. However, the average MvNO switching time is similar in both cases showing that the MvNO selection mechanism performs well in every scenario.

Finally, Figure 5 presents the correlation of the MvNO switching time for case (a) in those 6 time-slots that the experiment occurred in. It can be seen that the minimum MvNO switching time is stable in every time-slot. However, the average and the maximum values are higher in the

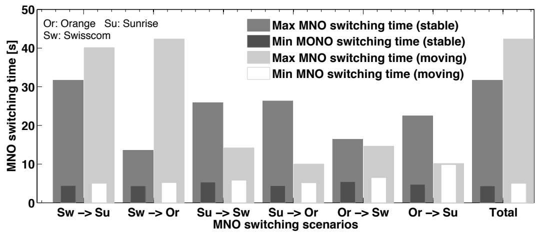

Figure 4. Min and Max Values for the MvNO Switching Time

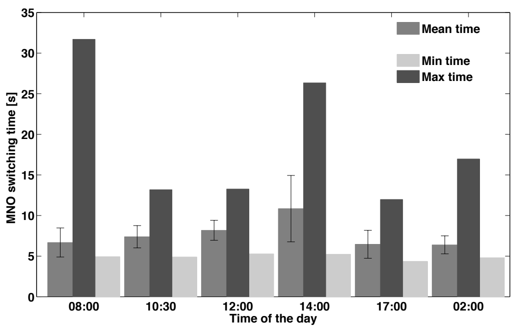

Figure 5. MvNO Switching Time During the Day

morning and early in the evening.

5.1.2. MvNO Switching Energy Consumption. The power consumption is critical in a mobile system. If a mechanism would absorb a large amount of available energy resources within a few network hops, the MvNO switching mechanism would not be usable in practice. Hence, a detailed evaluation of the power consumption has been made. To measure the power consumption, the battery level was determined before the test run and after the test had been performed according [1]. The difference of these levels lead to the final battery consumption in percentage of the battery energy. The assumption is that the battery health is in ideal condition. This assumption is appropriate, because the device of those measurements and its battery was new and experiments were performed in an ideal temperature for the battery [13]. This procedure was applied, since currently no Android application exists, which can measure the real battery capacity, or no application is in place, which measures the consumed energy per application accurately.

During the test the display of the device remained turned off, as well as every irrelevant to the experiment process was disabled. In the test case (a), where the location was stable, the measured power demand of the MvNO switching mechanism was 0.5406 W. The same test has been performed in test case (b), while moving from Zürich to Lucerne by train were the power demand was 0.6536 W. By comparing these values of both tests, the MvNO selection mechanism power value is comparable to the power consumption of the talk mode in 3G networks, which is calculated considering manufacturer's maximum stand-by and talk-time in 2G and 3G networks. Thus, the power consumption of an MvNO

TABLE 1. POWER CONSUMPTION EVALUATION

Process	Power [W]
Talk 3G	0.7050
MvNO selection moving	0.6536
MvNO selection stable	0.5406
Talk 2G	0.3333

switching compared to other services, such as a hone call is shown in Table 1.

6. Conclusion

Callers are able to maximize their QoE by influencing the end-to-end cost of a call and QoS-related parameters, such as the sound quality and guaranteed network access. Thus, callers can benefit from lower prices and/or better services. MvNOs can offload traffic in congested network scenarios by increasing the requested values of MTR, and when there are enough unused resources to "attract" by lower MTR callers in the network and monetize idle and costly existing infrastructure.

A demand from technology makers, such as mobile OS SDK providers, is to provide public methods that allow to select the MvNO without any interaction with the UI. The implemented automatic and on-demand MvNO selection mechanism could and must be multi-platform available to facilitate AbaCUS. A properly implemented automatic and on-demand MvNO selection mechanism will also be possibly more energy and time efficient because the internal GSM modem methods that perform MvNO's selection is possible to be available to software developers and optimized for every platform.

Policy makers, such as regulation authorities in an AbaCUS moderated market will have an observer role instead of their juristic role today. Less regulation demands will result in a competitive market with all those benefits that the AbaCUS approach implies. Finally, the automatic and on-demand MvNO selection mechanism is powerless unless a SIM card can be registered in any MvNO. Thus, either the MvNO must voluntarily allow such action, or policy makers must enforce it.

The stakeholders involved in the mobile call process are identified and for each stakeholder its incentives and actions needed have been identified. It was shown that liberating the MTR market is essential since (1) the caller who is the paying party will be able to define and influence the overall cost and quality of a call, (2) MvNOs are able to terminate calls for callees that do not belong to their networks and possibly get access to new revenue streams, and (3) the regulation and governmental authorities will be able to liberate a traditionally consider monopolistic market. Finally, a prototype automatic and on-demand MvNO selection mechanism assumed in AbaCUS, has been implemented and proved to be usable in real life scenarios considering (1) energy consumption, and (2) time consumption per MvNO hop. Thus, a liberated MTR environment is illustrated in this work.

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