On User-centric QoE Prediction for VoIP & Video Streaming based on Machine-Learning

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1. Monitor infrastructure performance & upload measurements on server
2. Customers upload their feedback using u-map clients on smartphones
3. Analysis & correlation of measurements and feedback
4. Recommendations, alerts, and reports are sent to all stakeholders
U-map runs a localization system, which positions the user at a Google map. There are pre-determined regions for the queries (e.g., entire city, island) or the user can indicate the region of interest using the GUI/touch screen and “drawing” a polygon or a path.
To ensure scalability, u-map is envisioned as a **cloud service**, taking advantage of **inexpensive & flexible** platforms.

**No extra cost** for monitoring.

Cost: **u-map software** includes

- Personalized recommendations
- QoE prediction
- DB maintenance & access control

u-map reduces overhead, administrative support & results in faster responses, better resource management, with **lower cost**.

Can be designed according to different **business** models, e.g., provider-driven or a third-party.
2.2.2. Consumer empowerment: boosting consumer choice and protection

All stakeholders in general support a broader focus on more empowerment of end users. Some of them believe that well informed consumers with a choice of suppliers will enable a more dynamic and responsive market to the benefit of consumers and industry. In that aspect all contributors pay great attention to the transparency especially in the context of bundled offers and net neutrality measures. In that respect several of the stakeholders think that BEREC should further work on avoiding the unjustified traffic management practices, stressing that measures taken out of commercial motivations might lead to discriminatory practices with a direct negative effect towards the consumers.

Despite the general support for strengthening the consumer protection, some of the stakeholders point out that consumer protection measures should complement and not supersede the legal framework for competition. One of the stakeholders is of the opinion that BEREC should not adopt decisions in the field of privacy and data protection in order not to cause confusion and legal uncertainty.

2.2.3. Service related developments

In its draft Strategy BEREC has envisaged undertaking additional work in the field of international roaming, net neutrality, special rate and/or cross-border services, mainly through developing common concepts, gathering and analysing data and will focus on the elaboration of better methodologies to ensure comparability of data with a view to ensuring better and monitoring.

In addition the stakeholders propose BEREC to undertake additional measures, as follows:

- In the field of international roaming - to work more in order to guarantee development and growing of competitive alternatives to mobile international roaming;

- In the fields of net neutrality and transparency, including quality of service - to envisage Pan-European transparency measures related to network performance (including disclose traffic management information and the quality of Internet access);

- In the field of cross-border services – dedicating more efforts to facilitating their provision, including through dissemination of the best practices existing in that field.
3.1 Information and consumer empowerment

In order for consumers to be empowered to exert pressure for competition to deliver promised benefits to consumers by way of lower prices, more choice, improved quality of product and service, etc., they need to: access information about the various offers available in the market; assess these offers in a well-reasoned way; and act on this information and analysis by purchasing the good or service that offers the best value to the customer. When any of these elements of the consumer decision-making process is absent or weak, consumers’ ability to drive effective competition is eroded (Figure 3.1).

Adequate consumer information is also important in driving effective competition in the communication markets in order to deliver sustained benefits to consumers in terms of increased choice, lower prices, appropriate quality and innovation. TIO data show that the main category of complaints is inadequate or incorrect advice at point-of-sale. But for competition to be able to fully deliver effective outcomes for consumers, two important elements are necessary.

(i). Consumers need to be empowered with the information, skills and confidence necessary to engage effectively within the competitive process. This requires that consumers are aware of the choices available to them, of the features, capabilities, prices, advantages and disadvantages of new services and technologies (so that they are able to properly assess the potential benefits) and also of the existence and ways of using some functionalities (e.g. number portability) that strengthen their ability to switch.

(ii). Consumers need to be able and willing to switch between service providers easily, cheaply, and quickly without undue effort, disruption and anxiety. Where this is not the case,

Conditions for effective competition to prevail include rational empowered consumers able and willing to switch from one supplier to another, asymmetric information, zero transaction costs and absence of public goods and externalities in consumption or production. Any deviation from this set of conditions prevailing in a so-called “perfect market” results in a degree of market imperfection or “market failure”.

Source: Australian Communication and Media Authority (2011)
QoWater-A crowd-sourcing approach for assessing the water quality. CySWater’15 CPS Week
**u-map** feeds the analysis platform with **real customer data**, so the analysis becomes more **accurate, relevant, faster**.
How does the performance of an infrastructure affect the customer experience?
Quality of Experience

**Webber-Fechner Law**

**IQX hypothesis**

### QoS metrics (examples for telecom services)
- Achievable data rate
- Throughput, delay, packet loss
- Number of resource units

### QoE metrics

**with techno-socio-economic-psychological terms**
- Preference on QoS or price
- Price, *willingness to pay*
- *Perceived* QoE (e.g., opinion score)
- Content
- Intrinsic indicators towards a service provider e.g., its *brand name*, perceived value/reliability searching mechanisms, other services

To define **user experience** is a very hard problem & to monetize it even harder!

### Table: QoE metrics formulas

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
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</thead>
<tbody>
<tr>
<td>Linear</td>
<td>$w_R R_i(z)$</td>
</tr>
<tr>
<td>Exponential</td>
<td>$w_R \left( t - e^{-h R_i(z)} \right)$</td>
</tr>
<tr>
<td>Logarithmic</td>
<td>$w_R \ln \left( h \left( R_i(z) - q \right) \right)$</td>
</tr>
<tr>
<td>Isoelastic</td>
<td>$w_R \left( h \left( R_i(z) + q \right)^h - t \right)$</td>
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We develop **user-centric service-oriented QoE** models based on network metrics, using supervised regression

- **Apply machine-learning and data mining algorithms**, such as: Decision Trees, Support Vector Regression, Artificial Neural Networks, Gaussian Naïve Bayes
- Find the set of predictors that minimizes the mean absolute error of a model (**feature selection**)
- **Train the models** based on **empirical measurements** collected from field studies

We have demonstrated this methodology for **VoIP, audio & video streaming**
Selects the ML algorithm that exhibits the best performance & its parameters *automatically*, given the input.

On user-centric modular QoE prediction for VoIP based on machine-learning alg. \[\text{[IEEE Trans. on Mobile Computing, 2015]}\]
Example: Video Streaming Service

- **Service type, content type**
- **Network performance**: e.g., packet loss ratio, jitter, signal strength and statistics from the last 15, 30, 60 seconds of session
- **Buffering** events (number, duration), video resolution, termination type, session duration, startup delay
- **User activity**: e.g., pause, seek, off-screen events (number, duration)

The startup delay, buffering ratio, and weighted mean resolution affect the QoE
Some observations and challenges

- Small-scale studies: **controlled** environment, potentially using **reliable** equipments
  - Difficult to “cover” a **representative** and **realistic** dataset (users, context, condition, etc)

- Large-scale studies: reaches potentially lots of people, and thus, includes a more **representative** set of users
  - Typically employing **inexpensive** (not necessarily **accurate**) equipments
  - More likely to obtain also erroneous or unreliable data

“**ground-truth**” about QoE: tension between subjectivity & reliability

Obtaining **reliable** measurements via crowd-sourcing/sensing, participatory, non-controlled field studies can be challenging.
Concluding remarks ...

Develop **non-intrusive reliable** methodologies for assessing the user perceived QoE & engagement and **learn more about user perception** is a fascinating research problem!

- Collect rich set of traces (e.g., logs, physiological data), from various applications (e.g., social networking) using different types of **non-specialized** hardware & software (e.g., monitors, cameras, eye-trackers, microphones, keyboard, biosensors, EEGs)
- “Isolate” the impact of various **contextual** (e.g., location, time, presence), **cultural, social, economical** (e.g., cost of service, willingness-to-pay), **physiological** aspects on QoE
- Sanitize, pre-process the traces to include reliable measurements
Related representative publications


5. QoWater—A crowd-sourcing approach for assessing the water quality. *CySWater’15 Cyber Physical Systems (CPS) Week, Seattle, USA*


8. *To Subscribe, or not to Subscribe: Modeling and Analysis of Service Paradigms in Cellular Markets*. *IEEE DySPAN’12*

Thank you for your attention!

Questions?

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