INTRODUCTION

Along with rapid technological advances, there has been a proliferation of new and innovative systems, services, applications, and end-user devices. Network management concepts are also evolving, and autonomic network management paradigms aspire to bring human-like intelligence to telecommunication management tasks. Thanks to these technical advancements, the fulfillment of customer demands and user experience requirements are becoming the main differentiators for the effectiveness of telecom operators and service providers. In this era of competition, poor customer experience leads to a chain reaction of negative word of mouth, pushing customers into the arms of waiting competitors. Today, humans are quality meters, and their expectations, perceptions, and needs with respect to a particular product, service, and application carry greater value.

Quality of experience (QoE) is a fast emerging multidisciplinary field based on social psychology, cognitive science, economics, and engineering science, focused on understanding overall human quality requirements. QoE is the blueprint of all human quality needs and expectations. Traditionally, technology-centric approaches based on quality of service (QoS) parameters have been employed to ensure service quality to end users. QoE expands this horizon to capture people's aesthetic and even hedonic needs. The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) defines QoE as “The overall acceptability of an application or service, as perceived subjectively by the end-user”[1]. Unlike ITU-T’s definition, which only links QoE with subjective human perception, we consider objective human factors as equally important aspects of QoE. We define QoE as a blueprint of all human subjective and objective quality needs and experiences arising from the interaction of a person with technology and with business entities in a particular context.

For understanding user and/or customer requirements, it is pertinent to know the communication ecosystem where various actors interact to produce the service life cycle. The term ecosystem has been used in various fields. In ecology, it is defined as “a system involving the interaction between a community of living organisms in a particular area and its non living environment” [2]. A cultural ecosystem is defined as “a collection of living things and the environment in which they live” in [2]; similarly, we define a communication ecosystem as “the systematic interaction of living (human) and non living (technology, and business) entities in a particular context.”

ABSTRACT

In recent years, the quality of experience notion has become a major research theme within the telecommunications community. QoE is an assessment of the human experience when interacting with technology and business entities in a particular context. A communication ecosystem encompasses various domains such as technical aspects, business models, human behavior, and context. For each aspect of a communication ecosystem, various models have been developed. However, few models have been designed to integrate all aspects of a communication ecosystem to understand human behavioral needs in a detailed and structured way. While existing models have produced the basic sketch of QoE modeling, more concepts and interdomain mapping are to be incorporated in order to have a clear picture of QoE in communication ecosystems. The aim of the current work is to build on the existing research being conducted in disparate disciplines about human behavior in order to provide a high-level model that can be adapted to many specific contexts and to encourage future research which examines these cross-domain relationships.

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Kay Connelly, Indiana University

Toward Total Quality of Experience: A QoE Model in a Communication Ecosystem

Khalil ur Rehman Laghari, Noel Crespi, Institut Telecom, Telecom SudParis
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BACKGROUND: SURVEY OF KEY QoE MODELS

A conceptual framework for QoE must integrate different perspectives from business, technology, context, psychology, and cognitive science to capture human needs and behavioral requirements. This framework should represent the converging approach that combines different approaches in business, technology, psychology, and cognitive science should be integrated into one framework. The QoE notion is rich in research and has a similar goal to provide a holistic and unified view of human behavior in a particular context. While psychologists and social scientists analyze human behavior, technical interactions represent service performance based on QoS models. Business people try to provide a better user experience by ensuring network and service providers' strategies and business models for their technological infrastructure, and how effectively they can utilize their resources to increase their profit by retaining customers as well as attracting new ones.

In a communication ecosystem, different domains interact with each other and may also have different approaches. For instance, technological aspects such as service features, end-user device functionality, and user contexts may have different vocabularies, semantics, and perceptions. The communication ecosystem is an example of such a system, and it is presented in Fig. 1. It shows the interplay between humans, technology, context, and business in a communication ecosystem.

Figure 1. Communication ecosystem.

In a communication ecosystem, business-to-business factors (pricing), but it is not an inherent QoE factor; whereas we believe that QoS parameters as part of the human objective QoE, and consider environmental and service factors as contextual aspects. Since their model targets multimodal human-machine interactions, they divide the QoS taxonomy into influencing factors and interacting variables. They categorize QoE factors into two parts: subjective and objective human attributes associated with QoE, and consider environmental and service factors as contextual aspects. Their model produces very interesting results that classifies QoE factors into two parts: subjective and objective human attributes associated with QoE, and consider environmental and service factors as contextual aspects. They also do not differentiate QoE parameter categories, but they focus on the subjective QoE model.

The ITU-T's G.1080 proposes a QoE model of customer care, cost, promotion, and brand image may influence customers to develop positive perceptions of a service. QoE models measure user experience of multimedia services. Their model produced very interesting results that classify QoE factors into two parts: subjective and objective human attributes associated with QoE, and consider environmental and service factors as contextual aspects. They also do not differentiate QoE parameter categories, but they focus on the subjective QoE model.
proposing quality of experience model

human domain

Table 1. Comparison of QoE models.

<table>
<thead>
<tr>
<th>Model</th>
<th>Human Roles and Human Demographic Attributes</th>
<th>Subjective QoE Factor</th>
<th>Objective QoE Factor</th>
<th>Technological Domain</th>
<th>Contextual Domain</th>
<th>Business Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yan Gong et al.</td>
<td>No</td>
<td>Limited</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Andrew Perkis et al.</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sebastian Møller et al.</td>
<td>No roles</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Limited</td>
<td>No</td>
</tr>
<tr>
<td>ITU-T G.1080</td>
<td>Unclear</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Limited</td>
<td>No</td>
</tr>
<tr>
<td>Kilikki’ Model</td>
<td>Yes</td>
<td>No Taxonomy Available</td>
<td>No Taxonomy Available</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>David Geerts et al.</td>
<td>Limited (user role only)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Khalil Laghari et al.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
</tbody>
</table>

**Table 1. Comparison of QoE models.**
Factors include subjective and objective QoE factors, whereas technological characteristics include QoS and end-user device parameters. A holistic QoE model is thus a conceptual representation of inter- and intradomain relationships in a communication ecosystem. Now we briefly define different concepts related to the QoE interaction model.

**Human Domain and Human Entity**

HUMAN DOMAIN AND HUMAN ENTITY

Objective QoE Factors

Subjective QoE Factors

Human Role and Demographic Attributes

Human QoE Factors

Figure 2. High level diagram for QoE interaction model in communication ecosystem.
Table 2. QoE factors and their evaluation process.

<table>
<thead>
<tr>
<th>Evaluation Methods</th>
<th>Example Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subjective</strong></td>
<td>Psychological: Ease of use, joy of use, usefulness, perceived quality, satisfaction, annoyance, and boredom.</td>
</tr>
<tr>
<td>For subjective QoE factors, the evaluation process includes methods such as Survey and user studies. These methods are popular for collecting subjective QoE factors. They are influenced by consumer interests and preferences, and are often affected by external factors such as service conditions and user experience. The evaluation methods are based on specific QoE requirements. For the technological domain, evaluation methods include Structured Equation Modeling and data mining (Rough Set Theory). These methods are used for analyzing QoE factors. Afterward, some statistical techniques (Pearson correlation, multiple linear regressions, ANOVA, or Structured Equation Modeling) are used to analyze the data. Normally, objective QoE factors are quantitative in nature; they could easily be mapped with influencing factors using some statistical method.</td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Physiological: Brain waves, heart rate, blood volume pressure, respiration, and skin conductivity. Cognitive: Memory, attention, human activity, human task performance, language and human reaction time.</td>
</tr>
<tr>
<td>For objective QoE factors, there are special physiological tools (e.g., Galvanic Skin Response (GSR) and Body sensors) used for capturing human biological parameters. While for cognitive data, human performance models (e.g. GOMS [12]) could be used to gather objective QoE data. Normally, objective QoE factors are quantitative in nature; they could easily be mapped with influencing factors using some statistical method.</td>
<td></td>
</tr>
</tbody>
</table>
Business Characteristics

A mediation process is an intervening process of factors between prediction and outcome factors into three main categories:

• Predictor factors
• Mediation factors (Fig. 3)
• Outcome factors

Social science models attempt to establish causal relationships between prediction and outcome factors or influencing factors, and they are used to explain or predict changes in outcome factors. In a communication ecosystem, we have three different stakeholders.

Typical and business solution (thus, the box around 

Business Characteristics closer in order to create an integrated technology and business characteristics with customer QoE (SLA) aspects to fix the responsibilities between enterprise business characteristics are related to service provider, and network operator). Inter-domain coupling.

Examples include temporal, spatial, technical, and climatic context.

The real situation of interaction can contain information about friends, enemies, connections, or affiliations between two neighbors, coworkers, and relatives.

The social aspects of context.

Virtual context:

An image of the real environment. However, it raises some privacy and security issues that also need to be considered.

It is possible for multimedia service providers to provide contextual and contextualized QoE by taking care of user contextual information.

CONTEXTUAL DOMAIN

I o o o i o i o i o i .

Contextual Entity

I o i o i o i o i i .

Real context:

I o o o i o i o i o i .

Virtual context: A i o i o i o i o i o i .

Social context: o o o o .

Contextual Characteristics

E o .

INTERDOMAIN MAPPING

INTERDOMAIN MAPPING

A o o o o i o i o i o i o i o i o i o o i o i o i o i .

A o i o i o o o o i o .

A i i o o .

A i o o o .

A i i o o .

A i i o o .

A o o o .

A i o o o .

A i o o .

A i o o .

A i o o .

A i o o .

A i o o .

A i o o .

A i o o .

A i o o .
In this section, we have focused on interdomain characteristics, which is not part of our investigation of QoE as measured by subjective QoE questionnaires and customer retention rates. After measuring each factor and determining their interaction as briefly presented here:

- **Predictors:**
  - Age, gender, human roles, and context
  - Business characteristics (pricing)
  - Technological characteristics (QoS)
  - Contextual characteristics (social context)

- **Moderators:**
  - Service features offered by the MSP, use of infrastructure to improve QoS.
  - QoS levels as measured by the operation and maintenance center (OMC) of the MSP.
  - Pricing as provided by VoD service concerning multiples domains; however, instantiation could also be instantiated for intradomain characteristics, which is not part of our investigation.

- **Outcome:**
  - Business strategy for the next three years
  - MSP gains a clearer understanding of the QoE in the current work.
  - MSP creates its main mapping, while these three same processes link business models, service features, and human roles, and/or upgrade their delivery mechanisms, and/or upgrade their delivery.

As the era of human-centric service and product design and delivery flourishes, the focus is shifting toward a multidisciplinary human-centric quality of experience approach. In this article, we have proposed a holistic QoE model by bringing all disparate pieces of the communication ecosystem together to understand total QoE.

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REFERENCES


Figure 4. QoE for VoD service.

BIographies

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