Overall Model Normalization towards Adequate Prediction and Presentation of QoE in Overall Telecommunication Systems

Stoyan A. Poryazov, Emiliya T. Saranova, and Velin S. Andonov

Abstract—**A method for QoE parameters prediction in an overall telecommunication system, consisting users and telecommunication network, based on QoS indicators' values prediction, is overviewed. Four normalization techniques are discussed. An indicators' Scale Normalization is proposed. Numerical illustrationis presented.**

Keywords—**Overall telecommunication system, Quality of Experience, Causal normalization, Functional normalization, Name normalization, Scale normalization.**

I. INTRODUCTION

The importance of perceived quality is stated as early as 1985[1], but Quality of Experience (QoE) of telecommunication systems became a commodity in 2015 [2].The QoE is defined in different ways, but we will follow the definitionin standardization documents such as the ITU-T [3]: The QoE is "The degree of delight or annoyance of the user of an application or service". The QoE effective determination, presentation, prediction and usage are important research tasks.

QoE depends on many factors, categorized in different ways:

EU Qualinet community [4] groups QoE influence factors into 3 categories: (1) Human Factors (e.g., gender, age, education background, etc.), (2) System Factors (e.g., bandwidth, security, resolution, etc.), and (3) Context Factors (e.g., location, movements, costs, etc.).

Skorin-Kapov and Varela [5] categorize the QoE factors into 4 dimensions: Application, Resource, Context, and User.

Alreshoodiand Woods [6] use 6 factors: User, Technology, Content, Environment, QoS network impairments.

In this paper, we consider a method for QoE parameters prediction based on QoS indicators only, of an Overall Telecommunication System (OTS), including users and telecommunication network. The values of the QoS indicators are predicted from an analytical performance model of overall telecommunication system, on the base of known parameters' values of users' behavior and technical characteristics of the telecommunication network.

The proposed approach allows overall model normalization, using several normalization techniques. It was developed in the period 2006-2018 in [7-12]. The results allow overall normalization of the models for QoE prediction, on the basis of human behavior and network characteristics. The QoS and QoE indicators are presented scalable – they may be considered on every level, from virtual base device, through user and network subsystems of the overall system. Sections II – V consist of a generalization of our experience. Sections V and VI contain new results.In Section II Structural Normalization is considered briefly. In Section III – Functional normalization. In Section IV – Causal normalization. In Section V – Conceptual normalization. In Section VI – Name normalization. In Section VII – Indicators' Scales normalization, including some new proposals. In Section VIII – Numerical examples are presented. In Section IX – Discussion and future research directions.

II. STRUCTURAL NORMALIZATION

In the teletraffic paradigm, the hardware, software, and users of an OTS are often considered as composed of virtual devices (Note: resource is "Any set of physically or conceptually identifiable entities within a telecommunications network, the use of which can be unambiguously determined." – term 1.3 in [13]).The users generate and terminate call attempts and determine some traffic parameters, e.g. probability of repeated attempts, service durations etc. They may be free or busy,therefore, in a conceptual normalized performance model of an OTS, they areusually considered astraffic devices.

At the bottom of the structural conceptual model presentation, we [12] consider 'basic virtual service devices' that do not contain any other virtual devices. Following Böhm and Jacopini [14] our basic devices have mainly one exit and one entrance. Exception to this is the devices of type *transition*and the *copier*. Transitions may have one entrance and two exits or two entrances and one exit. The copier has one entrance and two exits.

By the [14], all complex service structures may be presented as compositions of basic virtual devices by means of their serial, parallel and cyclic connections.

In our normalization approach[12], the service has different stages (e.g. dialing, switching, ringing, etc.), each consisting

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of one or more phases. A service phase corresponds to a real service device. Typically, a service phase includes a service device and all necessary auxiliary devices such as queues, entry and exit, as well as correspondent service branches, caused of specific ending of the service, e.g. the waiting time before initiating a repeated call attempt.

The device structures are conceptually and graphically presented by virtual devices with one or more functions.

III. Functional Normalization

We consider mono-functional idealized basic virtual devices of the following types [12]: Generator; Terminator; Modifier; Copier; Director; Enter Switch; Server; and Transition. These functional device types are enough for the models used.

IV. Causal normalization

The reason for termination of the service in the real devices occurs with specific probability and has specific duration (mean service time). This is presented structurally by service branches and corresponding basic virtual devices, each reflecting a different reason of service ending. The service branches form the ‘causal structure’ of the modelled real service. The used causal branches correspond to the: *abandoned*,*blocked*, *interrupted*, *not available* service and *carried*(successful attempt) causes [12].

Related Works: Many publications use the term “causal structures” (e.g. [15]).However, the nature of the parameters and the conversion of one structure into the other are usually not discussed.

V. Conceptual Normalization

We understand conceptual normalization as avoiding modeling concepts with overlapping and/or confusing meanings.

In the ITU-T definition, the carried traffic is “The traffic served by a pool of resources” (Term 5.5 in [13]). This definition leads to confusion between terms ‘carried’ and ‘served’.

For more precise traffic characterization in a pool of resources, we propose[11] the following definitions.

Definition 1: The Served Traffic in a pool of resources is the traffic, occupying (using) resources in the pool.

Definition 2: The Carried Traffic in a pool of resources is the traffic, which was successfully served in the pool (and carried to the next service phase).

Definition 3: The Parasitic Traffic in a pool of resources is the traffic, which was unsuccessfully served in the pool.

In the above proposed definitions “served” and “carried”traffic are different terms. While in the ITU-T def. ([13], Term 5.5) the carried traffic is “the traffic served by a pool of resources”. We believe that this differentiation allows a better and more detailed traffic and QoS characterization.

Another case of used causal normalization is ‘call blocking’ concept. We distinguish call blocking due to insufficient number of network resources and call blocking due to busy called terminal, because the latter depends of the called user’s behavior, not of the network performance.

VI. Name Normalization

In our normalized conceptual models there are tens of virtual devices and their naming has an important role for understanding the processes and derivation of analytical expressions. The naming problem is complex: 1) It is convenient to use the same or similar names of the parameters in the conceptual, analytical and computer models; 2) It is desirable to meet the Name Design Criteria [16]. According to these criteria, the names should be user-friendly. A user-friendly name takes into account the human user’s point of view, while neglecting the computer’s. It should be easy for people to deduce, understand and remember it.

Each base virtual device has a unique identifier, containing the abbreviations of the branch exit, branch name and stage, to which it belongs:

Device name = <branch exit><branch name><stage>

Each of the device parameters names is a concatenation:

Parameter name = <qualifier><parameter type><device name>

Qualifiers are, for example, ‘dem.’ standing for ‘demand’; ‘ofr.’ – for ‘offered’ etc.

Parameter types are (c.f. [13] for the definition of the terms): F – incoming rate of the requests’ flow or intensity; P – the probability with which the requests are sent to the device; T – duration of service in the device (of a request); Y – intensity of the traffic [Erlang]; V – volume of traffic [Erlang – time unit]; N- capacity of the device.

Related works: Qualifiers are used in [13]. However, no attempt to include qualifiers in the names of the parameters is made there. Name normalization is used in the data bases normalization processes. Name normalization in service performance models, proposed by other authors, was not found.

VII. Indicators’ Scales Normalization

The key quality indicators, in telecommunications, are defined in the ITU recommendations. They are of different types. In any case, we use the following natural assumption, based on the popular phrases “high quality” and “low quality” and propose here:

Assumption 1: The “best quality” is greater than “worst quality”.

The types of QoS indicators values vary:

- Qualitative - quantitative;
- Discrete - continuous;
- Have different ranges;

- Indicators may be a decreasing (e.g. blocking probability) or increasing (e.g. call efficiency ratio) function of the corresponding QoS.

Some QoE indicators and methods of their measure, are based on a score called 'mean opinion score' (MOS) and are defined in [17]. MOS is increasing qualitative scale: Excellent = 5; Good = 4; Fair = 3; Poor = 2; Bad = 1(the range is [1, 5]). On the other hand, the answer of some questionscan be presenting using discretescores: Yes = 1 and No = 0 [17].

Except different ranges and discreteness, the biggest problem with MOS is that arithmetical operations such as computing mean and standard deviation cannot be applied on qualitative values (e.g., "excellent" and "fair"), because the distance between these alternatives cannot be known. Therefore suchoperations must not be applied [18].

There are numerous publications where representations of QoE as a function of QoS are proposed [18]. In these representations of the QoE through the QoS, the opposite directions of change of the functions, the mishmash of qualitative and quantitative scales and other discrepancies cause difficulties. From the other hand, the presentation of QoS and QoE values in one plot, using the same scale is very useful for comparison and easier decision taking. Therefore, a normalization of their presentation is necessary.

In our approach,proposed here, and using Assumption 1:

1. User satisfaction (e.g. QoE) and QoS parameters are presented as increasing, continuous real function of the quality, in the interval [0, 1], where 0 means 'No service' or 'No' and 1 means 'Ideal service quality", or 'Yes'.

The questions in the user surveys have to be in a compliance with Assumption 1; Decreasing QoS indicators may be presented with their compliment, for example probability of blocking (Pb) may be presented as call efficiency Ec = 1-Pb.

2. User satisfaction has to be measured as continuous, through, a manualmark on a linear scale (Section A.4.2.3 in [17]).

Related works: In [19] QoE is discrete, in interval from 1 (bad) to 9 (excellent). In [20] QoE is discrete, in the interval from 0 (no service) to 100 (excellent); In [21] five point continuous quality scale is used for the speech QoE assessment, in the interval from 'extremely bad' to 'ideal'; In [22] the interval scale for QoE measurement is from 0 (poor) to 1 (excellent).

VIII. Example

In the preparation of Fig.1, a normalized conceptual and analytical models of the OTS [12] and normalizations of QoS and QoE indicators' scales, proposed in this paper, are used.

The OTS has: limited number of homogeneous terminals and users, generating primary and repeated (after failure) call attempts; losses due to abandoned, interrupted, blockagedue to lack of network equipment, blockage due to called terminal busy and 'not available service' cases; QoS guarantees due to virtual channel switching (Resource Reservation Protocol [23].

Network load is the ratio: (number of simultaneous busy terminals) / (all registered network terminals).

The QoS indicator Overall Network Call Efficiency(NCE) is the ratio (Number of successful call attempts) / (Number of all call attempts in the network), in the observed time interval.

The values of the QoE indicator (MOS of NCE), corresponding to the NCE,are calculated using a modification of the Weber-Fechner Law [24].

Note that in the point of theoretical maximum of the network load (100%), the QoS and correspondent QoE are zero ('No service' state).

The QoS indicator Overall Network Call Efficiency and correspondent QoE valuesare presented in the same proposed scale, in the entire theoretical interval of the network load.

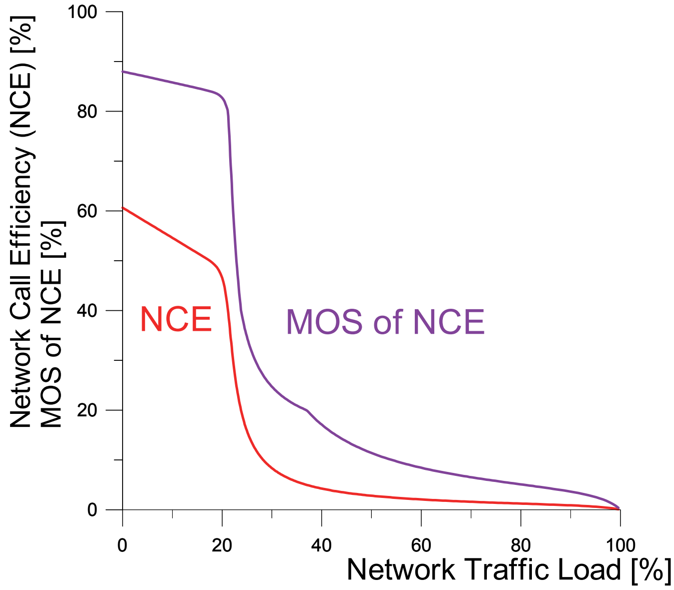

Fig. 1. Presentation of the QoS indicator Overall Network Call Efficiency and correspondent QoE values, in the same proposed scale, in the entire theoretical interval of network load.

IX. Discussion and Future Research Directions

Presented results show advantages of the proposed overall model normalizations techniques towards adequate prediction and presentation of QoE in conjunction with QoS, in the overall telecommunication systems.

The main challenge in the future research is including the user context factors in the QoE modeling and prediction methods.

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