Some User-oriented Indicators in Telecommunications

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Introduction

Users have to choose:
• network provider,
• tariff scheme and
• terminal devices
accordign their overall estimation of the Quality of Service (QoS).

Simply put, users make aggregation of observed characteristics of the telecommunication services and make decisions.

A very important task of the telecommunication researchers, designers and operators is to predict the user estimation of telecommunication services.
Motivation

An approach to this is the estimation of so-called ‘Quality of Experience’, or ‘Experience of Service’ parameters, based on the value prediction of telecommunication Quality of Service (QoS) parameters.

One of the problems of user experience prognostication in telecommunication services is the selection of Quality of Service (QoS) indicators, which reflect to a larger extent the users’ experience rather than the network providers’ one.
Task Formulation

We propose definitions and analytical expressions of four new overall network QoS time and traffic efficiency indicators, compared analytically and numerically.

• Some of them are mentioned in official documents, without any formal definition.

• They are more user-oriented indicators, compounding explicitly repeated attempts, effective duration of communication and total A-terminal occupation time.
We have been considered a model of overall telecommunication systems, including:

- users,
- terminals, and
- a network with Quality of Service (QoS) guarantees.

GSM, BSDN (Broadband Services Digital Network) and others, generalized virtual networks (VNET) with overall QoS guarantees, as an examples.
Fig. 1 Conceptual model of the telecommunication system, incl.: the paths of the calls, occupying A-terminals (\textit{a}-device), switching system (\textit{s}-device) and B-terminals (\textit{b}-device); base virtual device types, with their names and graphic notation.

Virtual Device Name = $<$\textbf{BRANCH EXIT}$>$<\textbf{BRANCH}$>$<\textbf{STAGE}$>$
Conceptual Model

The conceptual model includes users' behavior, a limited number of homogeneous terminals; losses due to 8 reasons:

1) abandoned and 2) interrupted dialing, 3) blocked and 4) interrupted switching, 5) unavailable intent terminal, 6) blocked and 7) abandoned ringing and 8) abandoned communication.

In our approach, the network traffic, terminal traffic for A (calling) and B (called) terminals have been divided and considered separately, in their interrelationships
The Analytical Model (1)

uses macro-state model of the system in stationary state, with: BPP input flow and repeated calls. Fourteen natural assumptions have been formulated.

We consider the values of 10 basic dynamic parameters, which are mutually dependent: 

\(Fo, Yab, Fa, \text{dem.Fa}, \text{rep.Fa}, Pbs, Pbr, \text{ofd.Fs}, Ts, \text{ofd.Ys}\).
Analytical Model (2)

We have chosen the intensity of the input calls flow $Fo$ as the independent input variable.

Thus, the considered system of equations has 9 generalized equations and 9 output dynamic parameters with unknown values (the main output variables).
Overall Network Efficiency Indicators in Use (1)

The network efficiency classical indicators are ASR, ABR and NER [ITU-T Rec. E.425 (03/2002). Internal automatic observations]:

**Answer Seizure Ratio (ASR)** = \( \frac{\text{number of seizures that result in an answer signal}}{\text{the total number of seizures}} \);

**Answer Bid Ratio (ABR)** = \( \frac{\text{number of bids that result in an answer signal}}{\text{total number of bids}} \);

ABR is similar to ASR except that it includes bids that do not result in a seizure;
Network Effectiveness Ratio (NER) is designed to express the ability of networks to deliver calls to the far-end terminal;

\[
\text{NER} = \frac{\text{(number of seizures)}}{\text{(the sum of the number of seizures resulting in either an answer message, or a user busy, or a ring no answer, or in the case of ISDN a terminal rejection (unavailability))}}
\]

These indicators reflect network providers’ attitude and exclude the possibilities of unsuccessful communication as well as the influence of repeated attempts.
Proposed
Network Efficiency Indicators
We use from the model considered output probabilities$^1$

- $P_{bs}$ - probability for blocked switching due to insufficient network equipment, and
- $P_{br}$ – probability for blocked ringing due to busy called B – terminal,

as main input for analytical determination and numerical prediction of the four proposed overall network QoS indicators for call efficacy

Successful Efficiency Indicator (1)

We have to determine the mean intensity of the input flow to the telecommunication system

\[ Fa = \text{dem.} Fa + \text{rep.} Fa. \]

\[ \text{rep.} Fa = Fa \cdot Pr. \]

It follows

\[ \text{dem.} Fa = Fa (1 - Pr). \]

\[ \text{dem.} Fcc = \frac{\text{dem.} Fa}{Fa} Fcc = (1 - Pr) Fcc. \]

where

\[ Pr = P_{\text{ad}} Pr_{\text{ad}} + (1 - P_{\text{ad}}) \left[ P_{\text{id}} Pr_{\text{id}} + (1 - P_{\text{id}}) \left[ P_{\text{bs}} Pr_{\text{bs}} + \right. \right. \]

\[ \left. \left. + (1 - P_{\text{bs}}) \left[ P_{\text{is}} Pr_{\text{is}} + (1 - P_{\text{is}}) \left[ P_{\text{ns}} Pr_{\text{ns}} + (1 - P_{\text{ns}}) \left[ P_{\text{br}} Pr_{\text{br}} + \right. \right. \]

\[ \left. \left. + (1 - P_{\text{br}}) \left[ P_{\text{ar}} Pr_{\text{ar}} + (1 - P_{\text{ar}}) \left[ P_{\text{ac}} Pr_{\text{ac}} + (1 - P_{\text{ac}}) Pr_{\text{cc}} \right] \right] \right] \right] \right] \right]. \]
We have defined Successful Efficiency, [extending ITU-T Rec. E.600] successful call definition: “A call that has reached the wanted number and allows the conversation to proceed”.

**Successful Efficiency** $(Es)$ (or Call Attempts Successfulness) is the ratio of all call attempts ended with successful finished communication (e.g. conversation) to all call attempts $(Fa)$.

$$ Es = \frac{Fcc}{Fa} $$

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1 S. Poryazov, E. Saranova. Generalized Aggregation Functions and Quality Indicators in Overfall Telecommunication Network Models. 8th European Symposium on Computational Intelligence and Mathematics, Sofia (Bulgaria), October 5th – 8th, 2016.
The main difference of Successful Efficiency indicator from classical indicators mentioned, is including in the Successful Efficiency all possible factors making information transfer unsuccessful (e.g. uncompleted), after it had been initiated.
Demand Efficiency Indicator ($Ed$) or Demand Call Attempts Successfulness Indicator

$Ed = \frac{\text{Number of first (demand) call attempts cause successful communication}}{(\text{All call attempts made, for these successful demand call attempts})}$

$$Ed = \frac{\text{dem.} F_{cc}}{F_a} = \frac{(1 - Pr)F_{cc}}{F_a} = (1 - Pr)Es$$

Demand Efficiency Indicator presents the probability of a demand (first) call attempt to become a successful call attempt.

It is a user-oriented indicator, compounding explicitly repeated attempts, connection and communication parameters.
Expressions ‘network time efficiency’ and ‘network traffic efficiency’ are used many times, in the papers devoted mainly to the road traffic. In [1], [2], [3], [4] and others, these phrases are used without definitions.

Definitions of ‘time efficiency’ and ‘traffic efficiency’ indicators for overall telecommunication networks were not found.

Proposed Network Efficiency Indicators

A. *Network Traffic Efficiency Indicator* \((E_y)\)

We propose the ratio (intensity of the carried communication traffic of A-terminals) to (intensity of the all A-terminals traffic) as a Network Traffic Efficiency Indicator \((E_y)\).

The intensity of the successfully carried communication traffic of A-terminals is obviously the carried traffic \((Y_{cc})\) in the \(cc\) device (Fig.1) and the intensity of the all A-terminals traffic is the carried one in the \(a\)-device \((Y_a)\)

\[
E_y = \frac{\text{successfully carried communication traffic of A-terminals}}{\text{intensity of the all A-terminals traffic}}
\]

\[
E_y = \frac{Y_{cc}}{Y_a}
\]
## Proposed Network Efficiency Indicators

### B. Network Time Efficiency Indicator ($E_t$)

$E_t$ is the proposed Network Time Efficiency Indicator. It is the ratio of (duration of successfully carried communication) to the (duration of the overall occupation of the A-terminals), multiplied by the Successful Efficiency of the call attempts.

\[ E_t = \frac{\text{Duration of successfully carried communication} \times \text{Successful Efficiency of the calls}}{\text{Duration of the overall occupation of the A-terminals}} \]
Proposed Network Efficiency Indicators

B. Network Time Efficiency Indicator ($Et$)

We have proven the Proposition: Time network efficiency ($Et$) and Traffic network efficiency ($Ey$) indicators are numerically equivalent.

\[
Ey = \frac{Ycc}{Ya} = \frac{Fcc \cdot Tcc}{Ya} = \frac{Fa \cdot Es \cdot Tcc}{Fa \cdot Ta} = Es \cdot \frac{Tcc}{Ta} = Et
\]
Proposed Network Efficiency Indicators

C. Demand Efficiency Traffic Indicator ($Edy$)

We propose the ratio (intensity of the carried communication traffic of A-terminals, caused from demand (first) call attempts ($dem.Ycc$)) to (intensity of the all A-terminals traffic ($Ya$)) as a

Network Demand Efficiency Traffic Indicator ($Edy$):

$$Edy = \frac{dem.Ycc}{Ya}$$
Proposed Network Efficiency Indicators

D. Demand Efficiency Time Indicator ($Edt$)

Network Time Efficiency Indicator $Edt$ presents:

(i) the probability of a demand (first) call attempt to become a successful call attempt;

(ii) The ratio of (duration of successfully carried communication) to the (duration of the overall occupation of the A-terminals).

$$Edt = \frac{\text{Duration of successfully carried communication}}{\text{Duration of the overall occupation of the A-terminals}}$$
Proposed Network Efficiency Indicators

D. Demand Efficiency Time Indicator \((\text{Edt})\)

It is a user-oriented indicator, compounding explicitly repeated attempts, effective communication duration and total A-terminal occupation time.

**We have proven the Proposition:** Demand Efficiency Time \((\text{Edt})\) and Demand Efficiency Traffic \((\text{Edy})\) Indicators are numerically equivalent.

\[
\text{Edy} = \frac{\text{dem}.Fcc \ Tcc}{Fa \ Ta} = \text{Ed} \frac{Tcc}{Ta} = \text{Edt}
\]
Numerical Prediction of the Proposed Indicators

Numerical results are presented in the whole theoretical network load interval – terminal traffic \((Yab)\) equals of 0% to 100% of the number of all terminals in the network.

The input parameters are the same, excluding:

(i) capacity of the network, given as percentage of the number of all terminals in the system,
(ii) the aggregated probability of repeated calls \((Pr)\).
Numerical Prediction of the Proposed Indicators

**Fig. 2.** Network Traffic Efficiency Indicator, $E_y$ and Demand Efficiency Traffic Indicator $E_{dc}$ in Case 1. $E_s = E_{dy}$, because there are not repeated attempts in the system ($Pr = 0$).

**Fig. 3.** Network Traffic Efficiency Indicator, $E_y$ and Demand Efficiency Traffic Indicator $E_{dy}$ in Case 2. Repeated attempts make worse the performance considerably.

**Fig. 4.** Network Traffic Efficiency Indicator, $E_y$ and Demand Efficiency Traffic Indicator $E_{dy}$ in Case 3. Blocking sharply make worse the network performance.
A model of Overall Telecommunication Systems, including users, terminals and network with Quality of Service (QoS) guarantees has been used for analyzing and development of overall network performance indicators.
Conclusion (2)

Four Network Efficiency Indicators are proposed:

A. Network Traffic Efficiency Indicator \((E_y)\)
B. Network Time Efficiency Indicator \((E_t)\)
C. Demand Efficiency Traffic Indicator \((E_{dy})\)
D. Demand Efficiency Time Indicator \((E_{dt})\)

Demand Efficiency \((E_{dy} = E_{dt})\) is the most sensitive user-oriented connection performance quality indicator, among those considered, of a telecommunication network with QoS guarantees. It is a suitable QoS indicator for Quality of Experience (QoE) prediction.
The results received are useful for QoS prediction as a base for future Quality of Experience prognostication, taking into account terminals’ load.

The users’ behavior is for the further study, as a base for more adequate QoE estimation.
Publication: The results in this presentation are described in:

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THANK YOU

Questions and remarks are welcome