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MODELING OF TELECOMMUNICATION PROCESSES IN AN OVERALL COMPLEX SYSTEM

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Overall telecommunication network performance for virtual networks with the quality of service (QoS) guaranties is considered. Experimental use of a computer algebra system is discussed. The numerical results of three main efficiency parameters of the overall network are presented as functions of the network state in the whole theoretically possible interval for telecommunication systems with losses due to lack of resources. The results might be used for telecommunication network planning and traffic management.

Рассматривается общая производительность виртуальных сетей с гарантией качества обслуживания. Обсуждается экспериментальное использование системы компьютерной алгебры. Численные результаты, полученные для трех основных показателей эффективности для телекоммуникационной сети в целом с потерями от нехватки ресурсов, представлены как функции состояния сети во всем теоретически возможном интервале. Результаты могут быть использованы при управлении трафиком и при планировании телекоммуникационных сетей.

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INTRODUCTION

In many cases network performance is vital for the efficiency of the distributed information processes, for example, in multicomputer computation and control, especially in real time.

Network Performance is “the ability of a network or network portion to provide the functions related to communications between users” [1]. We use the following approach for the definition of an overall telecommunication network [2]. Overall telecommunication network performance includes network performance of all connections’ attempts in an overall telecom network, from all access-network-head-points to all access-network-end-points, in the considered time interval.

In this paper, the overall performance is considered for (virtual) networks with QoS guaranties. Virtual network (VNET) is “a set of traffic flows of the same class crossing a link that is governed by a specific set of bandwidth constraints. VNET is used for the purposes of link bandwidth allocation, constraint-based routing, and admission control. A given flow belongs to the same VNET on all links” [3].

We consider VNET carrying Class 0 traffic (real-time, jitter sensitive, high interaction (VoIP, video teleconference) [4]). The VNET is with virtual channels switching, following the main method for traffic QoS guaranties — resource reservation [5]: “Bandwidth reservation is recommended and is critical to the stable and efficient performance of Traffic Engineering methods in a network, and to ensure the proper operation of multiservice bandwidth allocation, protection, and priority treatment.” The overall network performance is investigated in stationary state.

1. CONCEPTUAL MODEL

In Fig. 1, a reference model of a generalized VNET with overall QoS guaranties is presented. Calling users and terminals are noted with A; the called ones, with B. The considered overall QoS parameters are: the probabilities Pbs of blocked switching (probability in case when there are no free switching lines) and the probability of blocked ringing Pbr — when the intent B-terminal is busy.

For every virtual device we propose the following notation for its parameters. Letter F stands for the rate (frequency) of the requests’ flow [calls/s], P — probability for directing

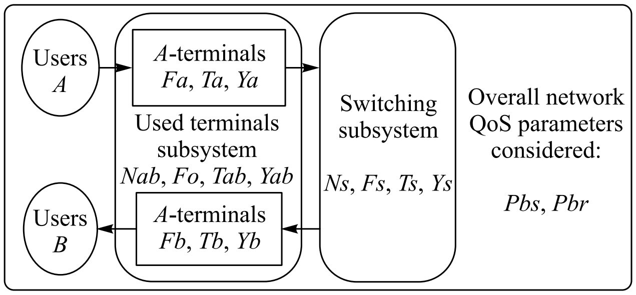

Fig. 1. Generalized VNET with overall QoS guaranties

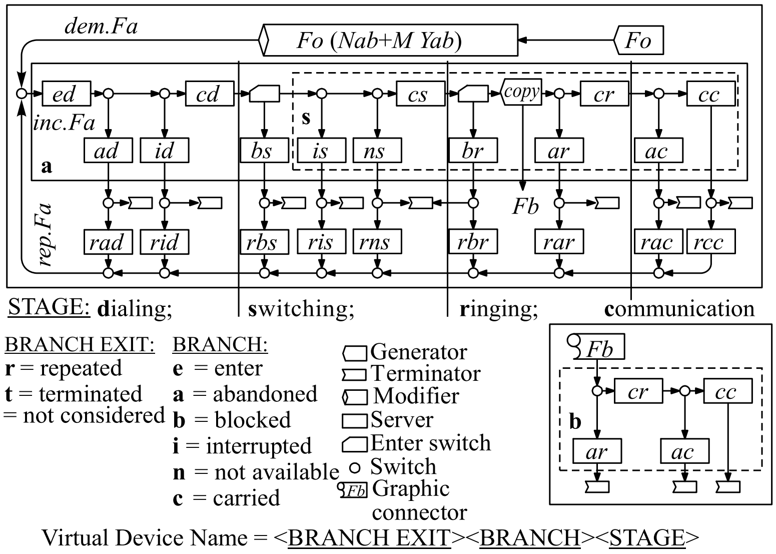

Fig. 2. Detailed conceptual model of VNET

the calls of the external flow to the device considered, T — mean service (holding) time [seconds], Y — intensity of the device traffic [Erl], N — number of service places (lines, servers) in the virtual device (capacity of the device).

A more detailed conceptual model is presented in Fig. 2. The following important virtual devices, comprising several basic virtual devices and shown in Figs. 1 and 2, are considered:

a — virtual device that comprises all the A-terminals (calling) in the system (shown with continuous line box);

b — virtual device that comprises all the B-terminals (called) in the system (box with dashed line in Fig. 2);

ab — this device comprises all the terminals (calling and called in the system (Fig. 1), not shown in Fig. 2.

More detailed explanations of the conceptual model, notation system, and assumptions made for the analytical model are given in [6].

2. ANALYTICAL MODEL

The basic parameter set consists of 31 static and 11 dynamic parameters [6]. For the static parameters we assume that their values do not depend on the state of the system and, correspondingly, on the intensity of the input flow in the considered time interval. The static parameters are: M, Nab, Ns, Ted, Pad, Tad, $Prad$, Pid, Tid, $Prid$, Tcd, Tbs, $Prbs$, Pis, Tis, $Pris$, Pns, Tns, Tcs, $Prns$, Tbr, $Prbr$, Par, Tar, $Prar$, Tcr, Pac, Tac, $Prac$, Tcc, $Prcc$ M is a constant, characterizing the BPP (Bernoulli (Engset) – Poisson (Erlang) – Pascal (Negative Binomial)) flow model of demand calls ($dem.Fa$) [7].

We consider the values of the following 11 basic (mutually dependent) dynamic parameters: Fo, Yab, Fa, $dem.Fa$, $rep.Fa$, Pbs, Pbr, $ofr.Fs$, Ts, $ofr.Ys$, $crr.Ys$.

Task Formulation: We consider the conceptual model of an overall telecommunication system, presented in Fig. 2. Parameters with known values are all static. The ones with unknown values are all dynamic. The task is to find analytic representation of the overall network performance. As independent parameter of the overall network system state, the terminal teletraffic Yab (it stands for the mean number of all simultaneously busy A (calling) plus B (called) terminals in the time interval considered) is chosen.

An important feature of our modeling approach is the distinguishing between the traffics of A (Ya) and B (Yb) terminals.

Under assumptions made in [6], a system of ten equations is received with:

— nine static parameters — six generalized (S_1, S_2, S_3, R_1, R_2, R_3) plus equivalent number of switching lines Ns, modifier M, and the number of used terminals Nab;

— eleven dynamic parameters.

If one parameter is chosen as an independent input variable, the system has ten equations with ten unknown dynamic parameters.

It is shown in [8] that all dynamic parameters can be expressed by one dynamic parameter (Yab), used as an independent input variable. The instant values of the terminal teletraffic are relatively easy to measure with counting the correspondent fields in memories of network controlling computers (or with Erlang-meters in the old analogous exchanges). For the past intervals, the needed information can be received from the CDRs (Call Detail Records), see [5, 9, 10], and other ITU-T Recommendations.

Used notation:

$$S_1 = Ted + Pad\,Tad + (1 - Pad)\,[Pid\,Tid + (1 - Pid)\,[Tcd + Pis\,Tis + \\ + (1 - Pis)\,[Pns\,Tns + (1 - Pns)\,[Tcs + 2\,Tb]]]],$$

$$S_2 = (1 - Pad)\,(1 - Pid)\,(1 - Pis)\,(1 - Pns)\,[2\,Tb - Tbr],$$

$$S_3 = (1 - Pad)\,(1 - Pid)\,[PisTis - Tbs + (1 - Pis)\,[Pns\,Tns + \\ + (1 - Pns)\,[Tcs + 2\,Tb]]],$$

$$S = (S_1\ - S_3\,Pbs)\,(Nab - 1) - \ S_2\,(1 - Pbs),$$

$$\alpha = (1 - Pad)\,(1 - Pid),$$

$$\beta = (1 - Pis)\,(1 - Pns),$$

$$\sigma = (S_3 - \alpha\,\beta\,Tb + \alpha\,Tbs\,)\,Nab + S_2 - S_3 - \alpha\,Tbs.$$

We need the following three dynamic parameters in the analytical expressions for the overall network performance: Pbr, Pbs, and the mean holding time (Ta) of the calling (A) terminals.

The mean holding time (Ta) in [11] is expressed as

$$Ta = S_1 - S_2(1 - Pbs)Pbr - S_3Pbs - \beta(1 - Pbs)(1 - Pbr)Tb,$$

probability of finding B-terminal busy (Pbr):

$$Pbr = \begin{cases} \dfrac{Yab - 1}{Nab - 1} & \text{if} \quad 1 < Yab \leqslant Nab, \\ 0 & \text{if} \quad 0 \leqslant Yab \leqslant 1. \end{cases}$$

Probability of attempts' blocking, due to insufficient number of switching lines Pbs, is expressed through the Erlang B-formula, by iterative calculations, from [8]:

$$Pbs = Erlang\_B\,\left(\frac{Yab\,[\sigma - (S_2 - \alpha\beta\,Tb)\,Yab]}{(Nab - 1)\,[S - S_2\,(1 - Pbs)\,Yab]},\, Ns\right).$$

3. OVERALL NETWORK EFFICIENCY PARAMETERS

1) "The fully routed call attempt" or "successful call attempt" (Definition 2.10 of [12] is "a call attempt that receives intelligible information about the state of the called user." This means: B-terminal is free, the calling user receives "ringing tone" and can understand whether the called user is present or absent. We call the corresponding ratio of successful call attempts to all attempts "B-efficiency" (Eb):

$$Eb = (1 - Pad)(1 - Pid)(1 - Pbs)(1 - Pis)(1 - Pns)(1 - Pbr).$$

2) Call efficiency (Ec) is the ratio of the successful calling rate (Fcc, "cc" stands for "carried communication") to the total rate of the incoming flow of A-terminals (Fa):

$$Ec = \frac{Fcc}{Fa} = Eb\,(1 - Par)(1 - Pac).$$

3) Traffic efficiency (Ey) is the ratio of conversational traffic (Ycc) to all traffic (Ya) of the A-terminals:

$$Ey = \frac{Ycc}{Ya} = Ec\frac{Tcc}{Ta}.$$

4. USE OF A COMPUTER ALGEBRA SYSTEM

Some computations, related to solving the formulated problem, can be performed using a computer algebra system (*Mathematica*, for example). We tried to obtain a symbolic solution of the main system of ten nonlinear algebraic equations using *Mathematica*. We got large, complicated, and not convenient for use expressions. That is why, having in mind the features of the equations, we developed an experimental algorithm for obtaining numerical solution of the system. Efficient *Mathematica* functions and program tools are used.

5. NUMERICAL RESULTS

Call efficiency (Ec), Traffic efficiency (Ey), and B-efficiency (Eb) depending on overall average traffic (Yab) in the system (system state), corresponding to one terminal (Yab/Nab), are shown in Fig. 3. Values of Yab are in the whole theoretically possible interval for telecommunication systems with losses due to lack of resources. The number of the available equivalent network lines (Ns) is 20% of the number of used terminals (Nab). The used input illustrative values are typical for voice systems.

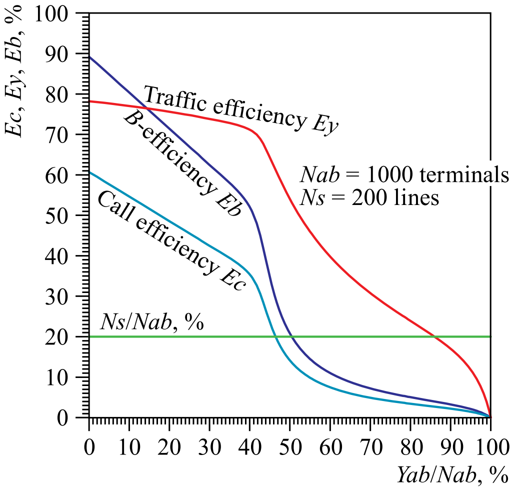

Fig. 3. Call efficiency (Ec), Traffic efficiency (Ey), and B-efficiency (Eb) for different normalized load of the overall telecommunication system Yab/Nab (%)

CONCLUSIONS

1. The overall telecommunication network performance for (virtual) networks with QoS guaranties is considered. It is shown that three main overall efficiency parameters (Call efficiency, Traffic efficiency, and B-efficiency (successful call attempts ratio)) can be presented as function of only a dynamic parameter — the traffic of all (called and calling) terminals (system state). The values of this parameter are relatively easy measurable.

2. The experimental use of a computer algebra system for solving the main system of algebraic equations can be considered as a good experience for further research in this field.

3. The numerical results of the three main overall network efficiency parameters are presented as functions of the network state of telecommunication system with losses due to lack of resources in the whole theoretically possible interval.

4. The results facilitate the telecommunication network planning, control, and traffic management, taking into account the traffic load, the available equivalent lines, and the three considered overall network efficiency indicators.

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