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NETWORK REDIMENSIONING, USING ITU E.600 OFFERED TRAFFIC DEFINITION

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Abstract:

Network redimensioning (medium term planning) means to determine volume of telecommunication resources, necessary to serve given traffic offered taking into account the prescribe Quality of services (QoS). Two different network redimensioning methods are considered in this paper. The aim of the research is comparison between network redimensioning method, using ITU E.600 traffic offered definition and our proposal, based on detailed users' behavior consideration. The received results are applicable for redimensioning of every (virtual) circuit switching telecommunication system. For networks in packet switching mode, proposed approach may be used as a comparison basis.

Keywords*: Overall Network Traffic, Offered Traffic, Virtual Circuits Switching, Network Redimensioning.*

ACM Classification Keywords: C.2.1 Network Architecture and Design; C.2.3 Network Operations; C.4 Performance of Systems.

1. Introduction

To determine the volume of telecommunication resources that is enough for serving given input flow of demands with prescribed characteristics of Quality of services (QoS), is one of the main problems that often have to be solved by operators.

To be redimensioned a network means, based on previous experience, to be found a number of necessary internal switching cirquits, so that in advance administratively determined level of Grade of services (GoS) to be achieved. QoS parameters are administratively specified in Service Level Agreement (SLA) between customers and operators.

The process of network redimensioning [ITU[1]-T E.734, 1996] is necessary for medium term traffic management in an advance determined level of GoS and is used to ensure optimal utilization of the existing equipment.

Based on the ITU definitions 2.8 and 4.12 in [ITU-T E.600, 1988], blocking probability due to lack of resources is used usually as target GoS parameter.

The aim of this paper is comparison between methods of network capacity redimensioning: our method proposed, based on a consideration of detailed users' behavior and requested QoS [Poryazov, Saranova 2006] and a network redimensioning method, using ITU E.600 offered traffic definition, as in [ITU E.501]. The results are graphically shown.

The received results are applicable and important for redimensioning/dimensioning of every (virtual) circuit switching telecommunication system, both wire and wireless systems working in circuit switching mode (e.g. GSM, PSTN, ISDN and BISDN, VoIP). For networks in packet switching mode, proposed approach may be used as a comparison basis.

2. Overall Network Redimensioning Method Proposed (ONRM)

2.1. Conceptual Model

The overall conceptual model of the telecommunication system [Poryazov, Saranova, 2006] includes the paths of the calls, generated from (and occupying) the calling (A) terminals in the proposed network traffic model and its environment (shown on Fig. 2). In this paper we consider model of telecommunication system with channel switching, in stationary state, with Poisson input flow, repeated calls, limited number of homogeneous terminals and losses due to abandoned and interrupted dialing, blocked and interrupted switching, not available intent terminal, blocked and abandoned ringing and abandoned conversation.

The names of the devices are constructed according to their position in the model.

The comprising virtual devices

The following important virtual devices on Fig.2 are shown and considered:

a = comprises all the A-terminals (calling) in the system (shown with continuous line box).

b = comprises all the B-terminals (called) in the system (box with dashed line).

ab = comprises all the terminals (calling and called) in the system (not shown on Fig.2);

[1] International Telecommunication Union

s = virtual device corresponding to the switching system. It is shown with dashed line box into the a - device. Ns stands for the capacity (number of equivalent internal switching lines) of the switching system and Nab is a number of A and B terminals in the network considered.

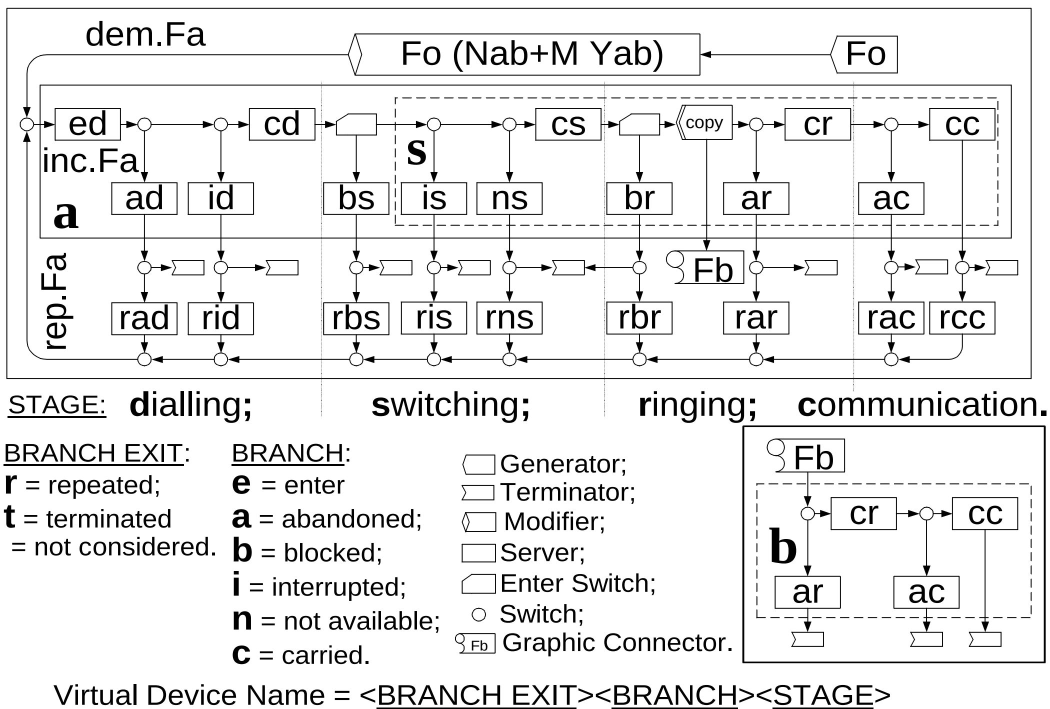

***Fig. 2**. Normalized overall conceptual model of the telecommunication system and its environment and the paths of the calls, occupying A-terminals (a - device), switching system (s - device) and B-terminals (b - device); base virtual device types, with their names and graphic notation.*

Stages and branches in the conceptual model:

Service *stages*: **d**ialing, **s**witching, **r**inging and **c**ommunication.

Every service stage has *branches*: **e**nter, **a**bandoned, **b**locked, **i**nterrupted, **n**ot available, **c**arried (correspondingly to the modeled possible cases of ends of the calls' service in the branch considered).

Every branch has two *exits*: **r**epeated, **t**erminated (which show what happens with the calls after they leave the telecommunication system). Users may make a new bid (repeated call), or to stop attempts (terminated call).

In the normalized models [Poryazov, Saranova 2006], used in this paper, every base virtual device, except the switch, has no more than one entrance and/or one exit. Switches have one entrance and two exits. For characterizing the intensity (incoming rate, frequency) of the flow, we are using the following notation: *inc.F* for incoming flow, *dem.F*, *ofr.F* and *rep.F* for demand, offered and repeated flows respectively. The same characterization is used for traffic intensity (*Y*).

M is modifier of incoming flow and *Fo* is calling rate generated from one idle terminal. *inc.Fa = Fa* is intensity of incoming flow, characterizing the flow of demand calls (*dem.Fa*).

Full parameters' set

In the conceptual model presented we have at least 35 important virtual devices (31 base and 4 (*a*, *b*, *ab* and *s*) comprising). These devices are important for our research because values of their parameters are specific for the characteristics and state of the modeled telecommunication system. Since every device has 5 main parameters (*P, F, T, Y, N*), the total sum of parameters is 175.

2.2. Analytical model of Overall Network Redimensioning Method proposed

For creating a simple analytical model, we make a system of fourteen (A-1 – A-14) assumptions. [Poryazov, Saranova, 2006]

Some general equations

For the proposed conceptual model we have derived the following system of equations:

$$Yab = Fa\,[S_1 - S_2(1 - Pbs)\,Pbr - S_3\,Pbs] \qquad (3.1.1)$$

$$Fa = dem.Fa + rep.Fa \qquad (3.1.2)$$

$$dem.Fa = Fo\,(Nab + M\,Yab) \qquad (3.1.3)$$

$$rep.Fa = Fa\,[R_1 + R_2\;Pbr\,(1 - Pbs) + R_3\;Pbs] \qquad (3.1.4)$$

$$Pbr = \begin{cases} \dfrac{Yab - 1}{Nab - 1} & in\ \ case\ of \quad 1 \le Yab \le Nab, \\ 0 & in\ case\ of \quad 0 \le Yab < 1. \end{cases} \qquad (3.1.5)$$

$$Ts = S_{1Z} - S_{2Z}\;Pbr \qquad (3.1.6)$$

$$ofr.Fs = Fa\,(1\text{-}Pad)(1\text{-}Pid) \qquad (3.1.7)$$

$$ofr.Ys = ofr.Fs\;\;Ts \qquad (3.1.8)$$

$$Pbs = Erl\_b\,(\,Ns, ofr.Ys\,) \qquad (3.1.9)$$

$$crr.Ys = (1 - Pbs)\;ofr.Ys \qquad (3.1.10)$$

The following notations are used:

$$S_1 = Ted + Pad\,Tad + (1-Pad)[Pid\,Tid + (1-Pid)[Tcd + Pis\,Tis + (1-Pis)[Pns\,Tns + (1-Pns)[Tcs + 2Tb]]]] \quad (3.1.11)$$

$$S_2 = (1-Pad)(1-Pid)(1-Pis)(1-Pns)[2Tb - Tbr] \quad (3.1.12)$$

$$S_3 = (1-Pad)(1-Pid)[PisTis - Tbs + (1-Pis)[Pns\,Tns + (1-Pns)[Tcs + 2Tb]]] \quad (3.1.13)$$

$$S_{1z} = Pis\,Tis + (1-Pis)[PnsTns + (1-Pns)(Tb + Tcs)] \quad (3.1.14)$$

$$S_{2z} = (1-Pis)(1-Pns)(Tb - Tbr) \quad (3.1.15)$$

$$R_1 = Pad\,\Pr ad + (1-Pad)(Pid\,\Pr id + (1-Pid)[Pis\,\Pr is + (1-Pis)(Pns\,\Pr ns + (1-Pns))Q]) \quad (3.1.16)$$

$$R_2 = (1-Pad)(1-Pid)(1-Pis)(1-Pns)(\Pr br - Q) \quad (3.1.17)$$

$$R_3 = (1-Pad)(1-Pid)\{\Pr bs - [Pis\,\Pr is + (1-Pis)[Pns\,\Pr ns + (1-Pns)Q]]\} \quad (3.1.18)$$

$$Q = Par\,\Pr ar + (1-Par)[Pac\,Prac + (1-Pac)\,Prcc] \quad (3.1.19)$$

$$K = Pis\,\Pr is + (1-Pis)[Pns\,\Pr ns + (1-Pns)Q] \quad (3.1.20)$$

3. Network Redimensioning Task Formulation and Parameters used (NRDT):

3.1. Parameters' classification based on values' determination and signatures used

We consider **target value** of blocking probability due to lack of sufficient switching lines and note it $trg.Pbs$. It is a QoS parameters, administratively determined in advance.

Empirical parameters' values are received after direct measurements (primary parameters) and calculations (secondary parameters) e.g. empirical carried and offered traffic intensity in switching system considered - $emp.crr.Ys$ and $emp.ofr.Ys$, respectively.

Parameters' values received as a result of **assumptions** are denoted by prefix $ass.$, e.g. $ass.ofr.Ys$.

Designed parameters' values are calculated on the base of target, empirical and assumed values in the design. Designed parameters' values are denoted by prefix $dsn.$, e.g. designed number of switching lines $dsn.Ns$ and designed traffic offered $dsn.ofr.Ys$.

Test parameters' values are denoted by $test.$, e.g. $test.Pbs$ is test value of probability of blocking switching. Test parameters' values are received during designed system tests or simulations.

3.2. Network Redimensioning Task Formulation (NRDT)

To be redimensioned a network means to find number of necessary internal switching lines, when an advance level of QoS is administratively determined ($trg.Pbs$). The values of empirical parameters are measured, or calculated on the base of measured values, in the case of already operating network.

Goal of Network Redimensioning: To determine the number of equivalent internal switching lines $dsn.Ns$ such that $dsn.Pbs \leq trg.Pbs$.

Known parameters' values in the Network Redimensioning Task (NRDT):

Target parameter: *trg.Pbs,* by supposed value *Nab* when *Nab* = *adm.Nab* (number of administrative registered active terminals).

Parameters with empirical values: $emp.Fo$ (resp. $emp.dem.Fa$) and all holding time intervals and probabilities for all stages and branches, therefore $S_1, S_2, S_3, R_1, R_2, R_3, S_{1z}, S_{2z}, Tb$ also.

Unknown designed parameters: $dsn.ofr.Ys$ - traffic offered and $dsn.Ns$ - number of equivalent internal switching lines.

Aim of NRDT: To determine *dsn.Ns* so that *Erl_b(dsn.Ns ,dsn.ofr.Ys)= trg.Pbs,* e.g. $dsn.Pbs(dsn.Ns, dsn.ofr.Ys) = trg.Pbs$

Analytical Solution of NRDT through Network Redimensioning Method (NRDM) - our proposal

For creating analytical solution we make assumptions as follows:

Assumptions: 1) $dsn.dem.Fa = emp.dem.Fa$, where $dem.Fa$ is demand calling rate, therefore $dsn.Fo = emp.Fo = Fo$;

2) $dsn.Nab = adm.Nab = Nab$;

3) Static parameters in a short time interval - all holding time intervals (except holding time for switching *Ts*) and probabilities for all stages and branches - are unchangeable because are comparatively independent of the state of the system, therefore $S_1, S_2, S_3, R_1, R_2, R_3, S_{1z}, S_{2z}, Tb$ are unchangeable also.

Analytical Solution through our NRDM is made ([Saranova 2006], [Saranova 2008a], [Saranova 2008b]) on the basis of system equations (3.1.1) - (3.1.10) and the equation $dsn.Pbs = trg.Pbs$. In our network redimensioning method proposal, the traffic offered *ofr.Ys* and the number of internal switching lines *Ns* are derived as function of calling rate, generated from one idle terminal, *Fo* and probability of blocking switching *Pbs*.

On ***Fig. 2.*** are schematically shown the Input Parameters, Task Assumptions and Result Parameters of our network redimensioning method proposed.

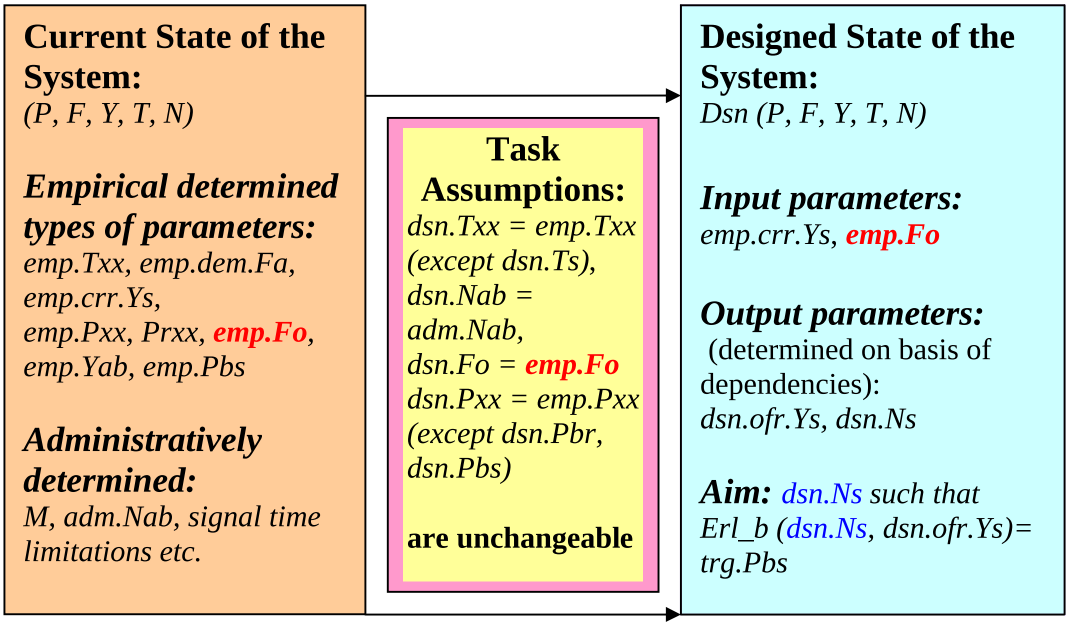

Fig.2. *Scheme according analytical NRDT solution – Input Parameters, Task Assumptions and Result Parameters our method proposed, based on the overall telecommunication system consideration.*

4. ITU Traffic Offered Definitions and Network Redimensioning Task Solution through method, using ITU E.600 traffic offered definition

We will apply ITU E.600 traffic offered definition for overall network redimensioning and after that we will make comparison between these results with the results of our network redimensioning proposal, using E.501 equivalent offered traffic definition.

4.1. ITU Traffic Offered Definitions

The main difference between the methods considered is based on the different manner of the traffic offered estimation and are conformable to the ITU Recommendation. [E.600, 1993] [E.501, 1997]

Traffic offered is defined as the traffic that would be carried by an infinitely large pool of resources. [E.600, 1993]

Carried traffic in [E.600, 1993] as the traffic that is actually serviced by telecommunications equipment is defined.

Equivalent traffic offered [E.501, 1997, Annex B (B-1)] is defined as the traffic estimated which produces the observed carried traffic in accordance with the relation; $crr.Ys = ofr.Ys(1 - Pbs)$, where $crr.Ys$ is the carried traffic, $ofr.Ys$ is the equivalent traffic offered and Pbs is the call congestion through the part of the network considered.

Estimation of the equivalent traffic offered $ofr.Ys$ in high usage-group and in only-path circuit group is based on the carried traffic $crr.Ys$ and follows formula:

a) $crr.Ys = ofr.Ys[1 - Erl\_b(Ns, ofr.Ys)]$, where $Erl\_b(Ns, ofr.Ys)$ is the Erlang loss formula, Ns is the number of working circuits and $crr.Ys$ is traffic carried on the high-usage group [E.501, 1997, (5-2)].

b) $ofr.Ys = crr.Ys / [1 - Pbs]$, where Pbs is the measured overflow probability [E.501, 1997, (5-3)]. It is recommended to apply both methods a) and b).

When **no significant congestion** in only-path circuit group then traffic offered $ofr.Ys$ will equal traffic carried $crr.Ys$, measured according to Recommendation E.500 $ofr.Ys = crr.Ys$.

4.2. The Network Redimensioning Task Solution derived from ITU Traffic Offered Definitions

Known parameters' values, unknown designed parameters and the aim in the Network Redimensioning Task, in both cases (when traffic offered estimation is in accordance with ITU E.600 and ITU E 501), are the same as in 3.2. in this paper.

4.3. Analytical Solution of Network Redimensioning Task through Method, using ITU E.600 traffic offered definition.

Assumptions: 1) $dsn.dem.Fa = emp.dem.Fa$;

2) The number of equivalent switching lines is an infinitely large pool of resources (ITU E.600 definition), e.g. $ass.Ns \to \infty$.

It means that $ass.Ns$ is more than *adm.Nab*, $Pbs \to 0$ and $ass.ofr.Ys = ass.crr.Ys$. Based on ITU E.600 traffic offered definition $dsn.ofr.Ys = ass.ofr.Ys$. Therefore $dsn.ofr.Ys = ass.ofr.Ys = ass.crr.Ys$

Analytical Solution is made on the basis of Assumptions 1-2. and equation *Erl_b(dsn.Ns, dsn.ofr.Ys)= trg.Pbs* .

Computer program, based on the inverse calculation of recursion Erlang B-formula in term of *dsn.Ns*, is made, for both methods considered. The recursion Erlang B-formula is

$$Erl\_b(dsn.Ns, dsn.ofr.Ys) = \frac{dsn.ofr.Ys * Erl\_b(dsn.Ns-1, dsn.ofr.Ys)}{dsn.Ns + Erl\_b(dsn.Ns-1, dsn.ofr.Ys)}$$ and

$Erl\_b(0, dsn.ofr.Ys) = 1$.

From numerical point of view, the follow linear form is most stable [Iversen 2004] and we preferred for calculating this formula

$$I(dsn.Ns, dsn.ofr.Ys) = 1 + \frac{dsn.Ns * I(dsn.Ns-1, dsn.ofr.Ys)}{dsn.ofr.Ys}, I(0, dsn.ofr.Ys) = 1,$$

where $I(dsn.Ns, dsn.ofr.Ys) = \dfrac{1}{Erl\_b(dsn.Ns, dsn.ofr.Ys)}$.

This recursion formula is exact, and even for large values of *dsn.Ns* and *dsn.ofr.Ys* ([Iversen 2004]). The received results for numerical inversion of the Erlang's formula (for finding the number of switching lines *Ns*) was confirmed with results of others commercial computer programs.

5. Test of the network redimensioning method considered

The test procedure includes the following steps:

1. Estimation of the two designed traffic offered values, based on a overall network teletraffic model, through both methods considered in this paper;

2. Determination of the two designed number of switching lines *dsn.Ns*, necessary to serve the two estimated traffics offered and the one and the same target QoS;

3. Simulation of the state of the telecommunication system after the network redimensioning, on basis of the two designed numbers of switching lines received (*dsn.Ns)*;

4. Recording of the both test values of traffic offered ($test.ofr.Ys$) and respective test probabilities of blocking switching ($test.Pbs$), where $testPbs = Erl\_b(dsn.Ns, test.ofr.Ys)$;

5. Making comparison between both values of $test.ofr.Ys$ and the target value $trg.Pbs$.

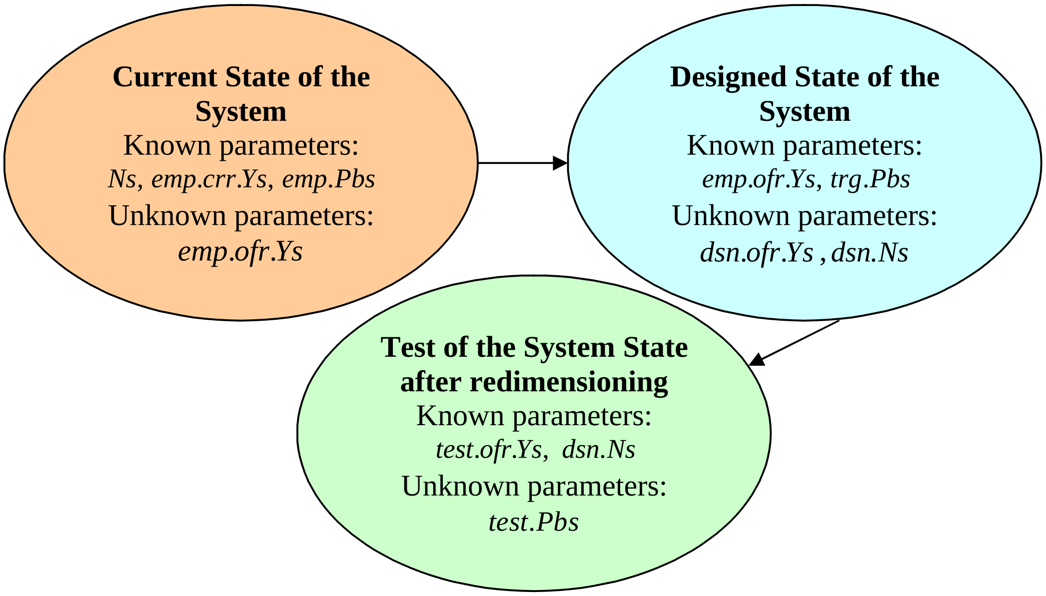

Fig.3. *Scheme concerning analytical NRDT solution and making test of received results.*

Computer program is made for finding test values of the probability blocking switching $test.Pbs$ regarding both network redimensioning methods considered in this paper, where $test.Pbs = Erl\_b(dsn.Ns, test.ofr.Ys)$.

6. Numerical Results

Using follows parameters' values numerical results are received:

Ted = 3 sec, *Pad* = 0.09, *Tad* = 5 sec, *Prad* = 0.95, *Pid* = 0.01, *Tid* = 11 sec, *Prid* = 0.2, *Tcd* = 12 sec, *Tbs* = 5 sec, *Pis* = 0.01, *Tis* = 5 sec, *Pris* = 0.01, *Pns* = 0.01, *Tns* = 6 sec, *Prns* = 0.3, *Tbr* = 5 sec, *Par* = 0.65, *Tar* = 45 sec, *Prar* = 0.75, *Tcr* = 10 sec, *Pac* = 0.2, *Tac* = 13 sec, *Prac* = 0.9, *Tcc* = 180 sec, *Prcc* = 0.01, *Tb* = 139.07 sec, *Tcs* = 5 sec, *emp.Fo*=0.0125714, *Nab*=1000 terminals.

On ***Fig.4.*** the dependence of test probability of blocking switching *testPbs* from normalized traffic intensity Yab/Nab is presented.

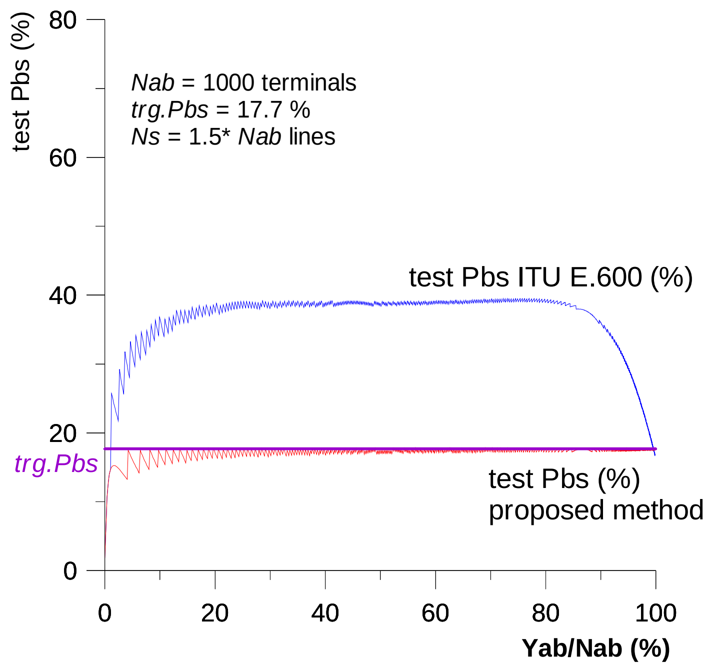

Fig.4. *Comparison of the test values of the blocking switching probabilities* $(test.Pbs)$ *regarding both network redimensioning methods, where* $testPbs = Erl\_b(dsn.Ns, test.ofr.Ys)$.

Based on the values of $test.Pbs$, calculated through the two different network redimensioning methods, and shown in Fig.4., follows:

1) Designed number of internal switching lines, necessary for servicing of test traffic offered, that is determined through our network redimensioning method proposed, is more than the exact value, needed for receiving the $trg.Pbs$. More precisely: $trg.Pbs - 4.5\% < test.Pbs < trg.Pbs - 0.0005\%$ in 99 % of the whole theoretical interval. By reason of this, the graphics of $test.Pbs$ on basis of our network redimensioning method is under the line $trg.Pbs$ on ***Fig.4.***, i.e. the designed blocking probability due to lack of resources is less than $trg.Pbs$ and desired predetermined QoS level is reached. The goal of Network Redimensioning, to determine the number of equivalent internal switching lines $dsn.Ns$ such that $dsn.Pbs \le trg.Pbs$, is fulfilled satisfactorily.
2) The network redimensioning method, based on the ITU E.600 traffic offered definition, determine designed number of internal switching lines so that it is less than the necessary number, needed for receiving the $trg.Pbs$. More precisely: $trg.Pbs + 21.6\% < test.Pbs$ in 99 % of the whole theoretical interval. Therefore the graphics of $test.Pbs$, on basis of network redimensioning method using ITU E.600, is over the line $trg.Pbs$ on ***Fig.4.***

3) Mean values of $test.Pbs - trg.Pbs$ is – 0.3 % according our NRD method proposed, and 14.2 % for the network redimensioning method, based on the ITU E.600 traffic offered definition, for 99.7 % from the whole theoretical interval.

Therefore, the accuracy of our network redimensioning method proposed is better in comparison with the method, based on ITU E.600 offered traffic definition. This is graphically shown on ***Fig.4.***

7. Conclusions

1. Detailed normalized conceptual model of an overall (virtual) circuit switching telecommunication system (like PSTN, GSM and VoIP) is used. The model is relatively close to the real-life communication systems with homogeneous terminals.
2. Two different methods for estimation of traffic offered and respectively two methods of telecommunication network redimensioning are considered. Our method proposed is based on detailed users' behavior consideration, desired Quality of Services and equivalent offered traffic definition, in [ITU E.501]. The other network redimensioning method is based on definition of the traffic offered in ITU E.600 recommendation.
3. The effects of the designed numbers of switching lines, received through both network redimensioning methods are researched through finding of test probabilities of blocking switching values. The numerical results are graphically shown.
4. The number of internal switching lines, received through our NRD method proposed, guaranties the target QoS.
5. The test numerical results of network redimensioning on basis of ITU E.600 traffic offered definition show that the designed number of switching lines is insufficient for serving with the target QoS.

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