Method for Estimating Parameters of NGN traffic

A. Krendzel[1], V. Derjavina[2], S. Lopatin[2]

***Abstract*--It is expected that the traffic in the next generation networks (NGNs) will undergo both quantitative and qualitative changes due to a large diversity of NGN services. As a result, the estimation problem of NGN traffic parameters becomes more complex. In this paper we present the method to evaluate the NGN traffic based on a probabilistic model of events initiated by calls of NGN services. It is proposed to make both a decomposition of NGN services into some classes in accordance with traffic they generate and a distribution of NGN users into some subgroups in accordance with a demand for different NGN services. The method enables estimating the main parameters for symmetrical and asymmetrical traffic separately depending on a type of NGN services generating the traffic.**

I. INTRODUCTION

The deployment of Next Generation Networks (NGNs) gives a possibility to create and support a broad range of different telecommunication and infocommunication services. The main purpose of NGNs is to enable users to get the information content they want, in any media, over any facilities, anytime, anywhere, and in any volume [1]. The examples of the most important NGN services that will be important drivers in the NGN environment are Voice and Multimedia Telephony; Data (Connectivity) services; Multimedia services; Virtual Private Networks (VPNs); Public Network Computing; Unified Messaging, Distributed Virtual Reality, Interactive Gaming, Information Brokering, E-Commerce, Call Center Services and others [1]. A large diversity of NGN services leads to dramatic quantitative and qualitative changes in parameters and nature of the data traffic.

In particular, there will be a considerable increase in the rate of transactions and in the total traffic intensity in NGNs. Besides, it is necessary to take into account the notion of self-similarity that will take place in NGNs due to the high variability of burstiness of the multiservice traffic [2,3,4]. For these reasons, the prediction problem of data traffic measures becomes very complex when planning NGNs. In this paper the estimation method for the main parameters of the NGN traffic taking into account the above-mentioned NGN features is considered. It is based on a probabilistic model of events initiated by calls of NGN services. It is proposed to perform both a decomposition of NGN services into some classes and a distribution of potential NGN users into some subgroups.

[1] Institute of Communication Engineering, Tampere University of Technology, P.O. Box 553, SF-33101, Tampere, Finland,
krendzel@cs.tut.fi
[2] LONIIS, St.-Petersburg Research Institute of Telecommunications, 11, Warshawskaya str., 196128, St.Petersburg, Russia,
derj@inser.loniis.spb.su

II. THE DECOMPOSITION OF NGN SERVICES INTO SOME CLASSES

The main feature of the NGN traffic is unique diversity depending on type of supported services. Therefore, it is reasonable to make a decomposition of NGN services into some classes on the assumption that services belonging to one subset will generate nearly equal traffic intensity.

In the first step of the decomposition, a set of NGN services is divided into two subsets. *The first subset* includes services concerning the real-time establishment of connectivity between endpoints. It is characterized by the transfer of the symmetrical traffic and the strict control of Quality of Service (QoS). Examples of such kind of services are traditional telephony, video-telephony, video-conferences and others. *The second subset* comprises of such services that generate the asymmetrical traffic, for instance, data (connectivity) services and multimedia services.

After that, each of the above-mentioned subsets of NGN services is divided into *three classes* in accordance with features of the generated traffic intensity. For instance, the following rules for such decomposition may be applied.

The decomposition of *the first subset* of NGN services creating symmetrical traffic into *three classes* is fulfilled taking into account the flow rate initiated by NGN users, namely

- the first class deals with services of traditional telephony since it is supposed that there will likely need to support various existing voice telephony services in NGNs. On provision of such services, network equipment should support the transfer of the bi-directional flow with the rate of 64 kbit/sec. Below, we denote the throughput of the channel as c_1 = 64 kbit/sec;
- the second class includes services of video-telephony. It is necessary to support the transfer of the bi-directional E1 flow (G. 702) from network equipment on the provision of such services. Hereinafter, the throughput of the channel is marked as c_2 = 2048 kbit/sec;

- and, the third class of the first subset of NGN services comprises of services requiring the transfer of some bi-directional E1 flows from network equipment for their supporting.

The decomposition of *the second subset* of NGN services initiating the asymmetrical traffic into *three classes* is fulfilled taking into account an amount of information initiated by users, namely

- the first class of services of the second subset deals with a transfer of a small amount of information (E-mails, Web-pages and so on) about w_1 = 1 kbit/transaction on average;
- the second class are characterized by a transfer of information about w_2 = 100 kbit/transaction on average (a transfer of texts, relatively small fractions of audio and visual information);
- the third subset comprises of services, which deal with a transfer of a large amount of information about w_3 = 10 Mbit/transaction on average, for example, multimedia services.

It is assumed that an amount of incoming data from network to users is much more than an amount of outgoing data from users to network for NGN services belong to the second subset.

The initial information concerning a specific (per each class of services) distribution of the total amount of transactions in a busy hour (γ_i, i = 1,2,3) may be used as the numerical criterion for the decomposition of each of two subsets of NGN services into the classes. These initial parameters form the exhaustive set and may be denoted as

$$\gamma_i, \quad i = 1,2,3, \quad \gamma_1 + \gamma_2 + \gamma_3 = 1, \qquad (1)$$

where the index i=1, 2, 3 corresponds with the above-mentioned classes of NGN services.

It should be emphasized that NGN services belong to one class will generate the current traffic intensity that has a variance of values of parameters substantially smaller than one relating to the traffic intensity of the total NGN services set.

III. THE DISTRIBUTION OF NGN USERS INTO SOME SUBGROUPS

A demand for NGN services depends on both a solvency of users and tariffs on the services. Since it is supposed that tariffs on services from different the above-mentioned classes will be unequal then a non-uniformity of a distribution of services between users will be different for each class of services. In order to take into account this fact when estimating parameters of data traffic it is worthwhile to distribute all NGN users into some subgroups in accordance with their demand for NGN services from the different classes.

Parameters of the non-uniformity of the distribution of NGN services for each class may be considered as the input data. Usually the non-uniform distribution of incomes between inhabitants is characterized by the Gini coefficients in statistics [5,6]. It is reasonable to use the Gini coefficients in our method as well. Values of the Gini coefficients may be defined on a basis of statistical information and marketing research regarding a demand for NGN services.

Let the non-uniformity of a demand for NGN services of each class be defined as

$$K_{G,i}, \quad i = 1,2,3. \qquad (2)$$

Here $K_{G,i}$ is the the Gini coefficient for the i-th class of NGN services.

If the non-uniformity of the distribution of NGN services for each class corresponds to the Pareto law [7,8], then parameters of the Pareto distribution may be calculated as follows [9]

$$\alpha_i = \frac{0.5(K_{G,i}+1)}{K_{G,i}}, \quad i = 1,2,3. \qquad (3)$$

It is obviously that the least non-uniformity of the distribution will take place for the first class and the largest one will take place for the third subset, i.e.

$$\alpha_1 > \alpha_2 > \alpha_3 > 1. \qquad (4)$$

It is quite easy to distribute users in accordance with their demand for NGN services if given (3,4). As a rule for the distribution of users into some subgroups the following one described below may be applied. As an example, we distribute NGN users into three subgroups, however there are no any special restrictions for a choice of a number of subgroups.

The wealthiest users ("rich") producing 90% of a demand for NCN services from the third class are included into the third (j = 3) subgroup. Note that Lorenz curves corresponding to the Pareto distribution with the parameter α may be written as follows [9,10,11]

$$Q(\alpha, x) = 1 - (1 - F(x))^{\frac{\alpha-1}{\alpha}}. \qquad (5)$$

Using the Lorenz curves it is possible to determine the relative number of users in the "rich" subgroup (F_3) as

$$F_3 = 0.9^{\frac{\alpha_3}{(\alpha_3-1)}}. \qquad (6)$$

Let users from the third subgroup and the second subgroup create 90% of a demand for NGN services from the second class. Then the relative number of users in the second (j = 2) subgroup named "middle" is determined as

$$F_2 = 0.9^{\frac{\alpha_2}{(\alpha_2-1)}} - F_3. \qquad (7)$$

At last, the relative number of users in the first subgroup (j = 1) named "poor" may be found as

$$F_1 = 1 - F_2 - F_3 . \qquad (8)$$

The expressions (6,7,8) give the rule for the distribution of users into three subgroups in accordance with their demand for NGN services from the classes of NGN services defined in the previous section.

IV. THE ESTIMATION OF THE RATE OF TRANSACTIONS

The estimation of parameters for symmetrical and asymmetrical traffic should be made separately using the common probabilistic model. If we consider the NGN services that generate symmetrical traffic then this model deals with calls of the services. If we consider the NGN services that create asymmetrical traffic then the probabilistic model deals with transactions initiated by the services.

The decomposition of NGN services and the distribution of NGN users give a possibility to form the probabilistic model of the initiation of calls/transactions based on an intersection of events from two statistically independent exhaustive groups.

The events included in the first group are denoted by index i = 1,2,3. They correspond with demand for services from the first, the second and the third classes respectively. The events included in the second group are denoted by index j = 1,2,3. They correspond with demands initiated by users from the "poor", "middle" and "rich" subgroups respectively. The first group and the second group of events are exhaustive by a definition since the expressions (1,8) are true. It is supposed that these groups of events are independent, in other words, the probability of an intersection of the events are equal to the product of probabilities each of the events.

This probabilistic model of the events allows us to segregate nine segments from the common flow of calls/transactions initiated in a busy hour by procedures of such services supporting. A variance of values of parameters each of random flows will be less than one relating to the common flow. This is because of the above-mentioned rules of the decomposition of NGN services and distributions of NGN users.

Then the problem is to determine average values of the rate of calls/transactions between nodes of NGN network subsystem. It corresponds with an intersection of two events from two formed groups of events.

Below we consider the approach for the calculation of the specific rate of calls/transactions (λ_{ij}) per an user in a busy hour for nine (i,j = 1,2,3) intersections of events from two above-mentioned groups of events. It is based on the solution of tree systems of equations that are formed for each of the classes of NGN services.

Note that each system of equations may be assigned on a basis of values β_{ij} where β_{ij} is a share of calls/transactions in a busy hour relating to users of the j-th subgroup when services from the i-th class are initiated, i,j = 1,2,3. In vector-matrix form the system of nine equations may be presented as follows

$$\mathbf{A_i \lambda_i} = \mathbf{0}, \qquad i = 1,2,3; \qquad (9)$$

where the matrix A_i is

$$\mathbf{A_i} = \begin{pmatrix} (\beta_{i1}-1)F_1 & \beta_{i1}F_2 & \beta_{i1}F_3 \\ \beta_{i2}F_1 & (\beta_{i2}-1)F_2 & \beta_{i2}F_3 \\ \beta_{i3}F_1 & \beta_{i3}F_2 & (\beta_{i3}-1)F_3 \end{pmatrix},$$

the column vectors are

$$\boldsymbol{\lambda}_\mathbf{i} = \begin{pmatrix} \lambda_{i1} \\ \lambda_{i2} \\ \lambda_{i3} \end{pmatrix}, \qquad \mathbf{0} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}.$$

The equation (9) is uniform. It has the nonzero solution only if matrices A_i are particular, i.e. their determinants are equal to zero. It is easy to show that this condition is true because rows each of the matrices are linear-dependent since a sum of all rows each of matrices A_i gives the zero row. The linear combination of any two rows of a determinant each of matrices A_i does not give the zero row. Thus a rank of matrices A_i is equal to 2 and a defect of matrices A_i is equal to 1.

Taking into account such features of matrixes A_i the system (9) has three one-parameter families of solutions

$$\lambda_{ij} = k_i C_{inj}, \qquad i,n,j = 1,2,3; \qquad (10)$$

where C_{inj} are algebraic cofactors of any row of matrices A_i; k_i are parameters of three families of solutions.

To concretize the solutions (10) it is necessary to add to the input data the value λ_{11} that may be quite easy estimated on a basis of statistical information concerning a demand for NGN services.

Then using (10) we obtain $k_1 = \lambda_{11}/C_{1n1}$ when i = 1. After that we select, for example, the row number three. For this row algebraic cofactors of the matrix A_1 are determined, i.e. $C_{131} = F_2F_3\beta_{11}$. Then we have a possibility to get the rest two solutions for the first family as follows

$$\lambda_{12} = \frac{\lambda_{11}\beta_{12}F_1}{\beta_{11}F_2}; \qquad \lambda_{13} = \frac{\lambda_{11}\beta_{13}F_1}{\beta_{11}F_3}. \qquad (11)$$

In order to find the family of solutions when i = 2 it is necessary to assign a value of the parameter k_2. For that it is worthwhile to use the input data defined in (1), i.e. values of the parameter γ_i, i = 1,2,3. Then it is possible to get the rest two families of solutions when i = 2,3 as

$$\lambda_{ij} = \frac{\gamma_i \beta_{ij} \sum_j \lambda_{1j} F_j}{\gamma_1 F_j}; \quad i = 2,3; \quad j = 1,2,3 \qquad (12)$$

Thus we have obtained the estimations (11,12) of the rate of calls/transactions in a busy hour for 8 segments of the data traffic generated by procedures of NGN services supporting. The value of the first segment (*i,j* = 1) are included in the input data.

V. THE ESTIMATION OF THE TRAFFIC INTENSITY GENERATED BY NGN SERVICES ON NETWORK NODES

In order to calculate the traffic intensity (the load) in Erlang, in addition to the rate of transactions it is necessary to determine the average call time/the average transaction time T_i (i=1,2,3) corresponding to procedures of NGN services supporting from the above-mentioned classes.

It is supposed that for *the first subset* of services the values T_i, i = 1,2,3 to be assigned on a basis of statistical information. In this case the traffic intensity on channels with the throughput c_i, i = 1,2,3 may be determined as follows

$$S_i = \frac{T_i \sum_j F_j \lambda_{ij}}{3600}, Erl. \quad i = 1,2,3. \tag{13}$$

So the total traffic intensity created by NGN services from the first subset (the symmetrical load) may be found as

$$S_s = \frac{\sum_i c_i S_i}{c_2}, Erl. \quad i = 1,2,3. \tag{14}$$

Since the throughput of channels in each class of services is different then the channel with the rate c_2 = 2048 kbit/sec is chosen as the basis one.

It is supposed that for *the second subset* of services the values of the average amount of information transferred during a transaction (w_i, kbit/trans) to be assigned on a basis of statistical data. Besides, it is necessary to add to the input data the value of the average rate of transferred data (c_i, kbit/sec) that are provided by access network recourses to support the required services.

The average transaction time corresponding to procedures of NGN services supporting from the second subset is

$$T_i = \frac{w_i}{c_i}, \text{sec}/trans. \tag{15}$$

The specific (per a user) traffic intensity generated by calls of NGN services belonging to the *i*-th class of the second subset in case if they are initiated by users from the *j*-th subgroup is obtained as follows

$$S_{ij} = \frac{\lambda_{ij} T_i}{3600}, Erl. \tag{16}$$

The traffic intensity created by calls from the *i*-th class of NGN services that are initiated by all users may be found as

$$S_i = \frac{T_i \sum_j F_j \lambda_{i,j}}{3600}, Erl. \tag{17}$$

Thus the expression for the estimation of the total traffic intensity created by NGN services from the second subset (the asymmetrical load) is

$$S_a = \frac{\sum_i c_i S_i}{2048}, Erl \tag{18}$$

Here the rate of the E1 channel has been also chosen as the basis rate.

At last, the total traffic intensity generated by NGN services on some E1 channels is

$$S_\Sigma = S_s + S_a \tag{19}$$

The obtained estimations give the values of parameters for separate segments of NGN traffic. It is worthwhile to use the estimations for effective NGN system planning. It should be also emphasized that when evaluating performances of network nodes and throughputs of trunk channels in transport network on a base of the estimations S_s and S_a, it is necessary to take into account that traffic patterns generated by NGN services may be quite different from traditional Poisson models used for circuit switched voice traffic and may have self-similar nature. According to [12] self-similar nature of the traffic may be taken into account assigning values 0.6….0.7 to the Hurst parameter.

VI. CASE STUDY ILLUSTRATING THE SUBMITTED METHOD

The example of the estimation of the parameters of the NGN traffic with a help of the above-presented method is considered in this section. In particular, the data traffic, incoming to/outgoing from the Packet Data Support Node (PDSN) of Network Subsystem (NSS) of the Third Generation (3G) wireless system on the first step deployment of the 3G equipment, is evaluated.

The initial data for the data traffic estimating are follows

- a number of users served by the PDSN equipment is 10^5;
- the percent of users that generate data traffic is 45%;
- the average data rate in radio channel is 50 kbit/sec;
- the load concentration factor in a busy hour is 0.1.

Besides, it has been taken into account the statistical information about a demand for various services. The calculations have been made using the approach and the expressions presented in previous sections. The most essential results of the data traffic estimating on the first step deployment of the 3G equipment are the follows

- the total traffic intensity is about 30 Erl in a busy hour;
- the rate of transactions per an user in a busy hour is
  - 0.60 trans/user for the first class of services (short messages);
  - 0.02 trans/user for the second class of services (pictures, texts, melodies transfer);
  - trans/user for the third class of services (multimedia services);
- the amount of user data encapsulated in IP-packets and processed by PDSN per month is
  - more than 1000 MB/month for short messages;
  - about 4000 MB/month for pictures, texts, melodies transfer;
  - about 160000 MB/month for multimedia services.

VII. CONCLUSION

Results of the study allow us to make the following conclusions:

- a large diversity of NGN services leads to both quantitative and qualitative changes in nature and measures of data traffic that make more complex the estimating problem of data traffic parameters;
- the presented methods gives a possibility to combine separated statistical data concerning the deployment of NGN services (based on packet switching) into the unified probabilistic model and to estimate NGN traffic parameters;
- the segment of the NGN traffic initiated by calls of services from the first class of the second subset create a small part of the traffic intensity on network elements, however, generate the most number of transactions;
- the segments of the NGN traffic initiated by calls of services from the third class of each subset give the main part of the traffic intensity;
- it is worthwhile to impose tariffs on NGN services depending on both a number of initiated transactions and an amount of transferred data.

The use of the submitted method allows making easier both the preparation of business-plans for development of wide range of NGN services and the preparation of system projects for deployment of NGN equipments.

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