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CAPACITY DESIGN OF LTE EPS NETWORK WITH SELF-SIMILAR TRAFFIC

Ageyev D.V., Qasim Nameer, Al-Anssari Ali. Capacity design of LTE EPS network with self-similar traffic. This paper proposes an approach to solve the problem of LTE EPS network parametric synthesis taking into account self-similar properties of multiservice traffic. The problem is solved with the known source data such as network topology, traffic routes, statistical data on the demand for information and communication services. The article proposes the calculation expressions to determine the parameters of multiservice self-similar traffic coming into the network, as well as aggregation of in different network elements. The solution is based on the representation of self-similar traffic as of fractal Brownian motion model and calculation expressions Offed by Norros. The proposed method in the paper was compared with the method based on the classical model of a Poisson flow. The experimental procedure is to calculate the parameters of the network by both methods and then checking the results of calculations using the simulation model. The analysis found that the use of the proposed method reduced the average delay time by 7-14%. The results of the simulation confirmed the results of analytical modeling, evidence of the adequacy of the models that have been used.

***Keywords*:** multiservice traffic self-similarity, LTE, EPS, synthesis method, traffic aggregation, modeling, parameter estimation, optimization, quality of service

Агеєв Д.В., Касім Намір, Аль-Анссарі Алі. Параметричний синтез LTE EPS мережі з самоподібним трафіком. У статті розв'язується задача параметричного синтезу LTE EPS при передачі в мережі мультисервісного абонентського трафіку з урахуванням його самоподібних властивостей. Розв'язок задачі базується на представленні самоподібного трафіку моделлю фрактального броунівського руху і розрахункових виразах запропонованих Норросом. Запропонований в статті метод був зіставлений з методом, що базується на класичних моделях пуасоновского потоку. За результатами аналізу встановлено, що використання запропонованого методу дозволило зменшити середній час затримки на 7-14%.

***Ключові слова*:** мультисервісний трафік, самоподібність, LTE, EPS, метод синтезу, агрегація трафіку, моделювання, оцінювання параметрів, оптимізація, якість сервісу

Агеев Д.В., Касим Намир, Аль-Анссари Али. Параметрический синтез LTE EPS сети с самоподобным трафиком. В статье решается задача параметрического синтеза LTE EPS при передаче в сети мультисервисного абонентского трафика с учетом его самоподобных свойств. Решение задачи базируется на представлении самоподобного трафика моделью фрактального броуновского движения и расчетных выражениях предложеных Норросом. Предложенный в статье метод был сопоставлен с методом базирующемся на классических моделях пуасоновского потока. По результатам анализа установлено, что использование предложенного метода позволило уменьшить среднее время задержки на 7-14%.

***Ключевые слова*:** мультисервисный трафик, самоподобие, LTE, EPS, метод синтеза, агрегация трафика, моделирование, оценивание параметров, оптимизация, качество сервиса

1. Introduction

Problem definition. Essential to ensure the effective functioning of EPS (including LTE RAN) is efficiency of network planning. It was from design methods, the adequacy of mathematical models used in this case, depend the properties and the viability of the future system.

One of the problems solved in the EPS network planning is to determine the types and performance parameters of the network nodes (MME, HSS, S-GW, P-GW, PCRF); capacities of communication channels; the number of used network interfaces; set eNodeB, associated with each of the network nodes EPS

The input data, which is typically used when solving LTE network planning problems are the number of subscribers, which requires the development of methods for determining the parameters of traffic and distribution of elements on its LTE network based on the types of user terminals and a variety of information and communication services provided by the network. As a result, it requires the development of traffic models and services.

Literature review. Modern research effort traffic in telecommunication network [1, 2] show that its statistical characteristics are different from those adopted in the classical queuing theory. This leads to the fact that traditional methods of calculating the parameters of telecommunications systems and their probability-time characteristics, based on the Poisson model and the Erlang formula gives unduly optimistic results, leading to an underestimation of the load. Recent studies of the properties of traffic in moderm networks have shown that the use of models of self-similar processes can more accurately describe the traffic transmitted in these networks.

Network performance degrades gradually with increasing self-similarity. The more self-similar the traffic, the longer the queue size. The queue length distribution of self-similar traffic decays more slowly than with Poisson sources. However, long-range dependence implies nothing about its short-term correlations which affect performance in small buffers. Additionally, aggregating streams of self-similar traffic typically intensifies the self-similarity ("burstiness") rather than smoothing it, compounding the problem.

The importance and the need for self-similarity effect in the traffic is confirmed including adopted ITU-T recommendation Q.3925 [3], which describes the value of Hurst parameter (parameter characterizing the degree of self-similarity) for any type of self-similar traffic.

In work [4] propose method for the planning problem of mobile core network of Long Term Evolution (LTE) namely Evolved Packet Core (EPC) based on realistic traffic parameters. More precisely, a set of equations is first proposed to generate a traffic profile while considering many realistic parameters. Then, a mathematical model is created to solve the planning problem of the evolved packet core of LTE networks while minimizing the cost. Numerical results show that the approximate approach is capable of providing good solutions (on average within 4.03% of the optimal solution) in shorter time duration than the exact approach. However, this method does not account for the presence of the self-similarity effect flows transmitted, which reduces the validity of this method in high loads on the network nodes. In addition to the use of traffic models are used profiles of aggregation of user traffic and are not considered part of the services provided and the proportion of the traffic generated by these services.

Consideration properties of self-similar traffic in LTE network can be due to use of approach equivalent bandwidth as proposed in [5]. This allows you to determine the required capacity of the communication channel for the transmission of a self-similar traffic, depending on the allowable probability of losses and allocated buffer size.

In [6-8] based on Norossa model [9, 10] proposed a method for determining the parameters of the aggregated group traffic and calculation of optimal network bandwidth. These methods can be applied in LTE EPC network planning. At the same time, these methods are not useful in the planning of network nodes, when it is necessary to take into account the characteristics of the quality of service separation requests.

Definition of quality of service parameters in the LTE EPC network nodes in an article [11], where presented mathematical models for the calculation of QoS parameters such as delay and loss probability taking into account properties of self-similar traffic. This modeling based on model P/P/1 with Pareto distri-bution function for between packet intervals and processing time for case then intervals between packets and the duration of processing on servers are limited.

Unsolvered tasks. On the basis of analysis of literary review we can suggest the following conclusions. Multiservice traffic going in advanced infocommunications networks, including LTE networks, is self-similar. Existing methods for LTE network planning based on the linear flow models and do not consider the effect of the presence of self-similarity. Thus there is a need to develop new models of services and the use of well-known models and theoretical expressions obtained for self-similar traffic for solving LTE EPC network planning.

Goal and research problems. The aim is to increase the efficiency of EPS LTE network planning for economic and technical parameters, taking into account set used types of user terminals and a variety of services provided by the network as well as taking into account the availability of self-similarity effect in transmitted flows.

To achieve this objective we need to solve next *particular tasks*:

– develop a method for evaluation of parameters of the incoming traffic from the subscribers or consumed by them;

– develop a method for determining the parameters of aggregation multiservice traffic for different elements EPS LTE network;

– selection of the calculated expressions to determine the quality of service parameters self-similar multiservice traffic.

2. Problem description

The problem which is solved in the article is that for a known network topology, traffic routes and load characteristics of the subscriber must identify the network bandwidth and the performance of the network nodes in the case of self-similar traffic.

Initial data are: B – set already installed eNodeB base stations; Z – set of EPS network nodes (Switch nodes, MME, HSS, S-GW, P-GW, PCRF); L – the set of communication channels that connect the nodes $z \in Z$; c_l – the throughput unit cost of the communication channel and $c_n(t)$ – costs for network node equipment with specified performance; π_{bz} – route of transmission of traffic between the node $b \in B$ and $z \in Z$; NU_b – number of subscribers in the coverage area of node $b \in B$; BHR_b – the proportion of attached (active) subscribers for the node $b \in B$; α_b^i – the proportion of a specific type of terminal (smartphone, tablet PC, the subscriber router, USB modem) for the node $b \in B$; S – set of services provided by the LTE network; $BHSA_{b\alpha}^s$ – number of session setup attempts for services $s \in S$ from subscribers in the node area $b \in B$; PR_b^s – penetration rate for services $s \in S$ from subscribers in the node area $b \in B$; ST_b^s – session duration (message volume) for services $s \in S$ from subscribers in the node area $b \in B$.

For each service $s \in S$ specified: β^s – sesion duty ratio; T^s – acceptable delay; P^s – acceptable probability of losses; traffic parameters: BR^s – traffic intensity; ζ^s – dispersion index; H^s – Hurst parameter.

While LTE EPS planning is necessary to find the configuration of the network, namely, to determine the characteristics (types) of installed network elements and network bandwidth to provide a minimum cost of network deployment. This can be represented as follows:

$$C_L(v) + C_N(X) \to \mathbf{min}\,, \tag{1}$$

where $C_L(v)$ – network construction cost (link and channels); $C_N(X)$ - installation costs of network elements (nodes).

3. Solution of the Problem

The problem to be solved can be divided into the following subtasks:

– determination of the parameters multiservice user traffic;

– determination of the parameters of traffic aggregation in the network elements;

– definition of quality of service parameters and formation of constraints.

The value of subscriber traffic depends on the number of active subscribers attached to base station eNodeB. Their amount can be determined from the expression

$$BH_b = NU_b \cdot BHR_b\,. \tag{2}$$

Then the value of the traffic at the base station eNodeB coverage area is defined as the amount of traffic of each service, given its prevalence

$$\lambda_b = BH_b \sum_{s \in S} \lambda_b^s \cdot PR_b^s\,. \tag{3}$$

The traffic generated by a single infocommunications services depends on the type of service (its profile) and the demand for this service

$$\lambda_b^s = \frac{BR^s \cdot ST_b^s \cdot \beta^s}{3600} \sum_{i=1}^{4} \alpha_b^i \cdot BHSA_{bi}^s . \qquad (4)$$

Other parameters of self-similar traffic coming from subscribers in the base station coverage area eNodeB such as the dispersion index and Hurst parameter defined according to both

$$\zeta_b = \frac{\sum_{s \in S} \zeta^s \lambda_b^s}{\sum_{s \in S} \lambda_b^s}, \qquad (5)$$

$$H_b = \max_{s \in S,\, \lambda_b^s < 0} \left(H^s\right). \qquad (6)$$

To determine the parameters of group traffic $\gamma_{ij} = \{\lambda_{ij}, \zeta_{ij}, H_{ij}\}$ in the communication channel (i, j), which occurs when aggregating multiple self-similar flows, each of which describes a model of fractal Brownian motion, proposed to use the following expression:

$$H_{ij} = \max_{(i,j) \in \pi_b} \left(H_b\right), \qquad (7)$$

$$\lambda_{ij} = \sum_{b \in B, (i,j) \in \pi_b} \lambda_b , \qquad (8)$$

$$\zeta_{ij} = \frac{\sum_{b \in B, (i,j) \in \pi_b} \zeta_b \lambda_b}{\sum_{b \in B, (i,j) \in \pi_b} \lambda_b} . \qquad (9)$$

The optimization mathematical model used includes following constraints in solving the problem.

The restriction on the maximum delay when transferring data. This value is defined as the sum of the delays in communication channels at the nodes of the network included in the route from the eNodeB to the Internet.

$$\sum_{(i,j) \in \pi_b} \tau_{ij} \le T^s, \quad \forall b \in B, \forall s \in S , \qquad (10)$$

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$$\tau_{ij} = \frac{\iota_{ij}}{c_{ij}} \left[1 + \frac{\lambda_{ij}^{2H_{ij} - 1/2\left(1 - H_{ij}\right)} \cdot c_{ij}^{1/2\left(1 - H_{ij}\right)}}{\left(c_{ij} - \lambda_{ij}\right)^{H_{ij}/1 - H_{ij}}} \right]. \qquad (11)$$

Restriction the probability of loss of Internet access, which is used for communication channels and network nodes

$$1 - \prod_{(i,j) \in \pi_b} (1 - P_{ij}) \le P^s, \quad \forall b \in B, \forall s \in S , \qquad (12)$$

$$P_{ij} = \exp\left[- \frac{\left(c_{ij} - \lambda_{ij}\right)^{2H_{ij}}}{2k\left(H_{ij}\right)^2 \zeta_{ij} \lambda_{ij}} \ell_{ij}^{2 - 2H_{ij}} \right], \qquad (13)$$

$$k\left(H\right) = H^H \left(1 - H\right)^{1 - H} . \qquad (14)$$

4. Results analysis

A study of the statistical characteristics of data flows transmitted through the connection piece of experimental network. During the experiment studied the traffic that occurs in the provision of various infocommunication services. As a result of the analysis confirmed the presence of traffic self-similarity properties and certain statistical parameters of traffic that then were used during the inspection validity of the results obtained by the proposed method in the synthesis.

LTE EPS parametric synthesis method which taking into account the properties of self-similar traffic was compared with the method based on the use of classical models of Poisson processes. In both cases, during the research used analytical models and then use simulation for verifying the results in this case.

The study found that the network LTE EPS, the parameters of which were determined by the method, based on the Poisson process models does not satisfy the requirements for delay in case of transfer traffic with self-similarity properties. The cost of the network which synthesized by proposed method is greater than by classic method. This explains the necessity of using a higher bandwidth when transmitting self-similar traffic. However, if a proportional increase bandwidth, so the cost was the same network, a network which synthesized the classical method, is 7-14% more value for the delay in the case of self-similar traffic transmission.

In this work the parametric synthesis method with the use of simulation. The method of the study was as follows. Problem was solvered for identical input data using the method, based on the Poisson flow model and using proposed method, which takes into account the presence of self-similarity effect. The results were used as parameters of the simulation model. The analysis of the experimental results confirmed earlier results obtained using analytical modeling, and received the results of simulation modeling delay value in packet networks were close to the theoretically expected using self-similar traffic models.

5. Conclusions

This paper proposes a set of mathematical models for solving the problems of parametric synthesis of LTE EPS networks. The model includes the following special models, such as a model of multicast traffic, as well as the calculated expressions to determine the parameters of the incoming traffic aggregation and self-similar traffic in the channels and network elements, as well as the expressions for determining probability-time characteristics.

It got a further development of LTE EPS cellular networks parametric synthesis method, due to the description of the information traffic in a network as model of self-similar processes. The analysis found that the use of the proposed method reduced the average delay time by 7-14% compared with the methods which are based on Poisson processes by more efficient use of network bandwidth and network elements LTE EPS. The results of the simulation confirmed the results of analytical modeling, indicating the adequacy of the models that have been used.

Developed method and its implementation is recommended for use in development organizations, at the stages of designing multiservice wireless cellular Infocommunication LTE networks, both newly constructed and reconstructed with the number of control nodes to several tens.

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