Simulation model of call service processes in a multiservice satellite network

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Abstract. This article is the result of developing a simulation model of a multiservice satellite network for such services as voice and data transmission. The presence of several types of services leads to the need to form several procedures in the model both by the type of traffic and by the direction of transmission. At the same time, one of the main limitations in the satellite network is the finite nature of the frequency resources used, leading to call losses when establishing a connection. To assess the probabilistic and temporal characteristics of the studied satellite network, such as qualitative performance indicators, a simulation model of a satellite communication network was developed taking into account a specified number of service provision procedures and the associated parameters of communication sessions and frequency resource distribution processes. The simulation model is implemented in the GPSS Studio environment (GPSS World language) and allows analyzing the probabilistic and temporal characteristics of the system, such as the probability of packet and call losses, and the average queue value when servicing multiservice traffic. The results can be used in the synthesis, analysis and optimization of satellite data transmission networks.

1 Introduction

Satellite communication network technologies make it possible to solve the problems of providing infocommunication services practically without restrictions throughout the entire territory of the globe [1-4]. In the Russian Federation, the use of satellite network technologies is also determined by the need to reduce the level of digital inequality, given that there are large spaces where it is impossible to build a ground-based backbone infrastructure, for example, for the Arctic region. Moreover, modern information resources have a large information capacity, therefore, in order to use them, it is necessary to provide users with channels with the appropriate bandwidth.

However, unlike terrestrial networks, satellite networks have large delays, which can be reduced by placing space systems in low orbits [3-6]. In this case, it will be necessary to additionally ensure the solution of additional problems, such as [1,2,6-8]: tracking changes

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in the position of the servicing spacecraft; supporting a large number of satellites in the orbital group; distribution of information traffic in both the satellite and terrestrial segments; etc.

A promising project being implemented in the Russian Federation, "Sphere", is aimed at solving various problems in the field of providing satellite systems services. One of them is providing broadband access to information resources throughout Russia, regardless of the availability of terrestrial communication channels [3,5,11,12].

Multiservice satellite networks use a large number of service provision procedures and related parameters to ensure communication sessions, as well as resource allocation processes. In this regard, simulation modeling can be used to check the operation and evaluate the probability-time characteristics (PTC) [6,7,9,10] of the data transmission network. When using simulation models to describe the processes of servicing information flows in satellite networks, it is necessary to describe the system with a certain accuracy, which will be sufficient for analysis [10,11].

2 The object of research

After reviewing and analyzing the standards of GSM, GMR, DVB-S2X, 3G technologies, the main procedures for modeling information flows in 25 frequency clusters (each cluster consists of a specified number of frequency zones - 150) of the modeled network were determined.

These procedures are:

1. Outgoing voice call;
2. Data transmission in the reverse direction (from subscribers to the base station);
3. Incoming voice call;
4. Data transmission in the forward direction (from the base station to subscribers).

In Figure 1, the procedures are designated as: procedure 1, procedure 2, procedure 3 and procedure 4, respectively.

Subscriber service is provided by using subscriber lines (SL), with six subscriber lines per feeder line.

In this work, an assessment of the intensity of information flows on all elements of the system was carried out, as well as an analysis of the PTC [5,9]. In the considered model, four procedures are implemented that allow one to obtain an idea of the loading of network elements by the main traffic flows present in the network under study.

The traffic generators in the developed model are the procedures for servicing incoming/outgoing voice calls and incoming/outgoing data transmission (Fig. 1). The generators that create calls and data packets are described by an exponential distribution law (Poisson flow) with a certain mathematical expectation, while it is possible to change the parameters of both this distribution and choose another probability distribution to describe the generation of the created traffic.

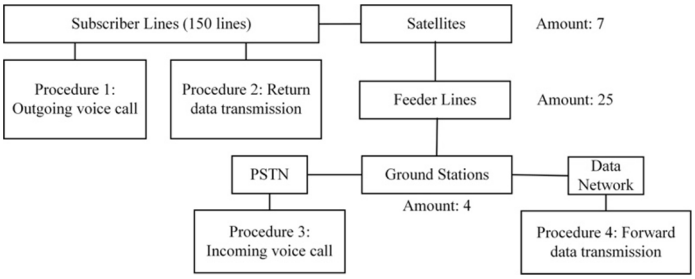

Fig. 1. Procedures and objects of the system.

Taking into account the need to provide multiservice access, the developed model implements modeling of the following types of traffic servicing processes: voice transmission (maximum speed up to 64 kbit/s); data transmission (maximum speed up to 4 Mbit/s). The values of the specified speeds are accepted as control and can be changed if necessary.

The service area for a subscriber is determined by the SL, the SL is served by the nearest satellite, connected by the FL with the GS.

3 Research methods

The GPSS Studio environment was chosen as a simulation modeling tool.

To create a simulation model taking into account the processes occurring during the servicing of information flows in the network under study, the necessary algorithmic support was developed for each procedure. As an example, Fig. 2 shows a generalized algorithm for the procedure of data transmission in the opposite direction [5,9].

As can be seen from the figure, when the satellite network resources are occupied at the FL and SL level, the subscriber's call goes through several stages, at each of which a specific request is generated or the availability of resources is checked. When all available resources are occupied, the call can be lost, which is taken into account in the call loss counter (later used to estimate the probability of losses taking into account the reason: due to the FL being occupied or the lack of free SL resources). When processing incoming calls to the ES, the number of lost packets is taken into account: the check is carried out in the "data transfer" block (Fig. 2), which allows us to estimate the probability of losses at the channel level.

In the simulation model developed in the GPSS environment [10], group objects are used to correctly describe the operation of the SL and FL. The frequency resource of the SL and FL is occupied discretely in accordance with the specified interaction protocol.

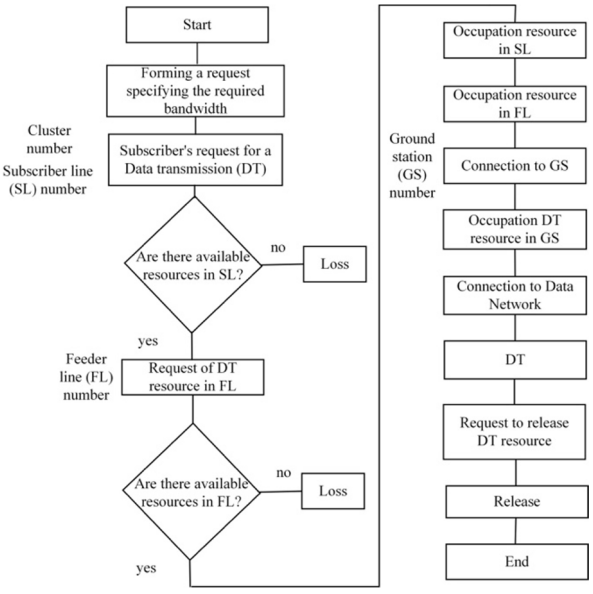

Fig. 2. Generalized algorithm of the data transmission procedure in the opposite direction.

For each call and transmitted packet, in the general case in the GPSS Studio modeling system such objects are called transactions, a set of certain parameters is formed during the generation of the transaction, for example, the parameters of the transmission rate, belonging

to the SL and FL, the choice of the procedure, the choice of the satellite for processing and transmitting the transaction, the choice of the GS, and other parameters. During the operation of the model, the parameters of the transactions can be changed if necessary. When generating transactions of the model, as calls coming to subscribers or from subscribers, the type of distribution of intervals between calls and the intensity of their receipt are taken into account.

The GS is presented in the simulation model as multichannel devices with a certain service intensity for PSTN and Data network. When transferring a call to the GS for service, subroutines are used, the operation of which is determined by the transaction parameters. In this case, it can be considered that the SL and FL models are identical when interacting with the GS and the satellite, therefore it is necessary to ensure automation of the process of constructing the network model as a whole. To solve this issue, a translator program was developed that translates the necessary procedure into the text of the simulation model in the GPSS language for its further use in the simulation model. Separate modules of the translator form cluster models (related to feeder lines), models of frequency zones in a cluster (correspond to subscriber lines), and models of earth stations. A generalized algorithm for the operation of the model text generator is shown in Fig. 3.

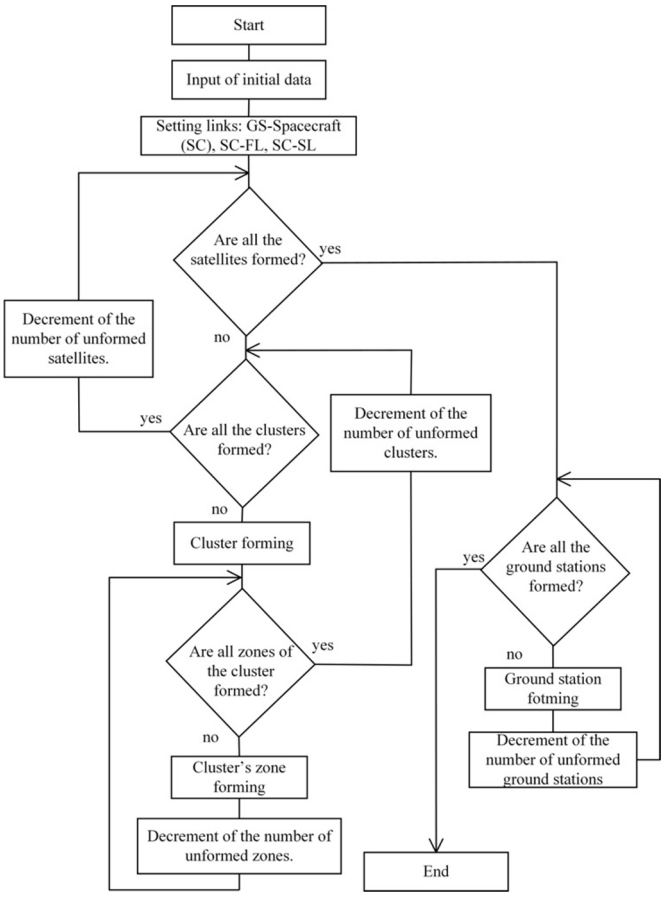

Fig. 3. Generalized algorithm of the model text generator.

Fig. 3 clearly shows that the model text generator is a set of nested cycles that form the text of the simulation model as a set of modules in accordance with Fig. 1: a satellite system module, a cluster module, a frequency zone module, and a earth station module.

When working with the simulation model text generator, it is taken into account that transactions are generated separately for each type of traffic, which allows for analyzing service characteristics separately for each type of flow during modeling. Also, the model text contains the frequency band distribution for each frequency zone, and for each cluster separately. Since the FL and SL bandwidth has limitations, the model calculates the number of lost transactions at each stage of the service process.

The obtained model text allows for the simulation of information flow servicing processes in the satellite network under consideration.

4 Results

The developed simulation model allows to study various characteristics of the satellite data transmission network. The main ones are the following PTC: probability of transaction losses, probability of line occupancy, probability of receiving transaction service, as well as characteristics determined either from standard GPSS statistics or from the analysis of the average queue values of the specified objects.

As a numerical result, Fig. 4 shows the dependence of the probability of losses due to the occupation of frequency resources of the feeder line on the upper limit of the requested band.

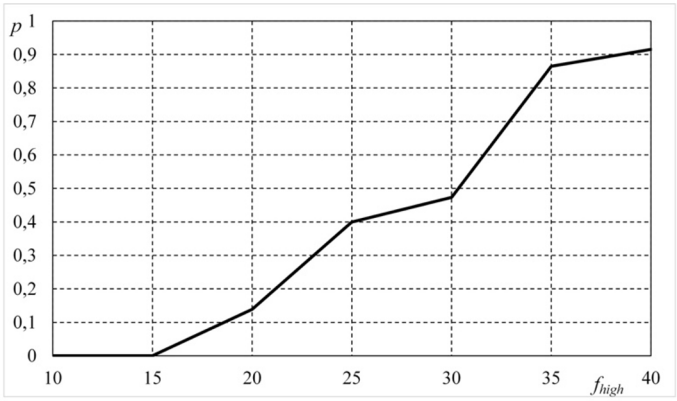

Fig. 4. Dependence of the probability of losses due to FL occupation on the upper limit of the requested band.

In the model, the upper limit of the requested bandwidth determines the maximum value for the random variable that specifies the frequency band for each call. The frequency resources are checked for FL availability before establishing a connection; at large values of the parameter under study, the number of calls that will be denied service increases, which is shown in the figure.

As a second example of the modeling results, Fig. 5 shows the dependence of the average queue in the earth station model buffer on the same parameter.

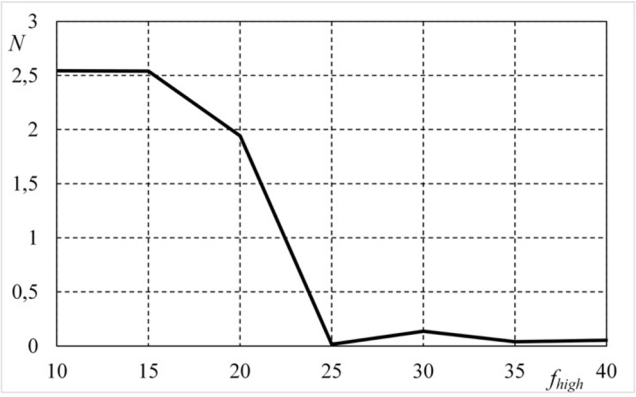

Fig. 5. Dependence of the average queue in the GS model buffer on the upper limit of the requested bandwidth.

Based on the examples of results obtained during simulation modeling, it is possible to draw a conclusion about the adequate operation of the developed software.

5 Conclusion

Within the framework of this work, a simulation model of a satellite data transmission network was developed, which allows to estimate the system's PTC at different stages of service. The model takes into account the limited frequency resource and describes its impact on the probability of call losses at each stage of service. The model also allows to analyze the characteristics of the system and their impact on the quality of service, which allows to determine the values of the system parameters to achieve certain reliability indicators. It should also be noted that by changing the parameters of transactions or parameters of the model service systems, it is possible to achieve an improvement in the quality indicators of the satellite network under study. It is worth noting that the hybrid model described in the work is a combination of the use of mathematical models of queuing theory within the simulation model.

Scientific novelty consists in: development of special algorithmic and software support allowing automation of the process of preparation of the program code of the simulation model; implementation of simulation models describing the processes of data transmission and call servicing for a multiservice satellite network; taking into account the limited frequency resources of the system, as well as ensuring the accounting of losses of transmitted data. The developed algorithmic and software support can be applied to data transmission networks of any scale and used in the synthesis of previously unknown and analysis of existing algorithms for traffic servicing in multiservice satellite data transmission networks.

Further study of the system is possible for non-Poisson flows, for other types of traffic besides voice traffic and data transmission, consideration of the system at other levels of the OSI model, and not only at the data link level.

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