SECTION 6. MATH

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6.1 Consideration of the main methods and directions of research in asymptotic analysis of stochastic networks

Mass service is a finite set of nodes - systems of service, among which circulating requirements, passing between nodes in accordance with the routing matrix. When considering networks and mass service systems, their structure and algorithm of operation are specified, and the function of time interval distribution between successive delivery requirements, service time distribution function, number of serving devices, and the length of the maximum possible queue is specified. For networks, the number of service nodes is additionally indicated. In the theory of mass service, the Kendal symbolism is used to denote the SMO: *A/B/L/N*, where *A* and *B* determine the types of distribution functions for the input flow of requirements and service time, *L* – number of servicing devices, *N* – number of waiting places. Instead of A and B, you can insert characters from such a set: {*M*, E_r, *HR*, *D*, *G*}, where M means an exponential distribution (Markovian), E_r – Erlang distribution of order r (Erlangian), *HR* – hyper-exponential distribution of order *R*, *D* – degenerate distribution (Deterministic), *G* – distribution of the general type (General) [304].

Under the network of service in the network understand the system of mass service, consisting of L ($0 < L \leq \infty$)the same service and buffer (queue) volume N ($0 \leq N \leq \infty$). At $L = 1$ the node is called single-line (single-channel), with $L = \infty$ – multichannel [305].

For those requirements that have completed the service in i - so the nodes are asked the probabilities of transitions to other nodes and the probability of leaving the network. Probabilities of transitions between nodes form a matrix of routing.

The external flow of requirements entering the network is determined by the coherent distribution of random variables, which are sequential intervals between the moments of receipt of claims. If these random variables are independent in aggregate, then such a stream is called a stream with a limited aftereffect, and for its definition it is sufficient to specify a set of distribution functions, where τ_k – the time interval between receipt $(k-1)$ and k - requirements. An important role in the theory of systems and mass maintenance networks is played by the recurrence stream, for which the Poisson flow is a special case of a recurrent stream $x \geq 0$, where is the flow rate.

In the theory of stochastic systems and networks, it is often assumed that the service time at the nodes of the network is exponentially distributed. This is due to the fact that requirements are processed at a constant rate, and the length of the requirement is a random variable distributed according to the index law. At the same time, most models are based on time-consuming process requirements and distribution of service time. However, in practice, there are real cases where the intensity of the input stream depends on time. This aspect encourages the use of heterogeneous time-based processes for modeling real networks. Natural is the assumption of the periodic dependence of the intensity of the input flow from timeto period of one day, week or month. Such models are much less explored than networks and systems with sustained-intensity flows. Some of the results can be found in the works [306].

Namely Lemoian investigated the asymptotic behavior of SMO with one maintenance device, an input Poisson stream, whose intensity is a periodic function of time and the general time of service requirements.

D. Hayman and W. Witt [307] reviewed the system $M_t \mid M \mid c$ and showed that, given the periodicity of the input stream, the process that describes the length of the queue is asymptotically periodic. The authors also obtained results regarding the strong asymptotic stability of the process describing the system. They set the ratio between the average number of requirements and the average time required by the system.

L. Brouwer [308] studied the type of SMO $BMAP \mid M_t \mid c$ (batch Markovian arrival processes), the input of which receives a periodic BMAP flow, the service time is distributed exponentially, and the intensity of service varies in time from time to time. Conditions of stability are proved in terms of intensities of receipt and maintenance. Special class is selected $BMAP|M_t|c$ - systems, in which it is possible to simplify calculations to the level of homogeneous SMOs.

The SMO with one maintenance device and the periodic intensity of service is studied in the monograph by M. van Eenig [308]. For such systems, the time axis is divided into intervals of equal length, called cycles. During the cycle the device serves different queues of requirements. The order in which he "visits" the queues is the same for each cycle.

GI Falin [309] developed an analytical approach to the diffusion approximation of the queue in the system $M_t|G|1|\infty$ with periodic input flow. The author uses the principle of averaging: the periodic queue is approximated by the corresponding stationary queue with the intensity of the input $\lambda = \lim_{t\to\infty}\frac{1}{t}\int_0^t \lambda(u)du = \Lambda$. We find conditions under which this approximation gives a good result. It is shown that the principle of averaging takes place for SMO in the conditions of high loading in the sense of convergence of the non-stationary process to the stationary one, which is a Brownian motion with reflection [310].

It should be noted that stochastic networks with periodic input flow have practically not been investigated.

A lot of work is devoted to the analysis of mass service models in conditions of overload mode of operation. An overloaded mode means that the characteristics of the model depend on some parameter n, and with $n \to \infty$ The average system load is one unit (or even more than one). The study of overloaded mode has a long history and distinguishes several areas oriented to different classes of models of mass service. Many authors have been dealing with incoming recovery processes, independent maintenance hours, and maintenance processes that are independent of the current queue and time length. For this case, the convergence of the characteristics of the normalized queue length to the solution of the differential equation or to the Brownian motion with reflection in the corresponding boundaries is proved. The methods of analysis in these works mainly use the functional central boundary theorems for the input stream, the process of maintenance and the routing process [311].

Another direction contains an analysis of Markov models of mass service, in which there is a dependence on the state of the system. In this case, the analysis method is mainly based on martingale technique. Using this technique, proved the convergence of the maintenance process in the network $\left[M \mid M_Q \mid 1 \mid c_n\right]^r$, which depends on the length of the queue, under the conditions of the overload mode of operation before the diffusion process. For networks of type $\left[M \mid M_Q \mid 1 \mid \infty\right]^r$ in the works the convergence to the diffusion process is investigated. Markov models, which depend on time, are considered in particular in the works. Some results for incoming processes depending on the network status and total distribution of service times are given in.

Not only for the development of the theory, but also from the practical point of view, it is important to examine the processes of service in general assumptions both in relation to the flow of requirements and in relation to the distribution of service time. It is commonly believed that the input flow with a very good approximation can be considered Poisson, at least in the tasks of telephony and tasks of information processing. This idea is based on the limit theorem on the total flow generated by many plurality of low intensity. Therefore, it is first and foremost important to study models in which the duration of service has an arbitrary distribution.

Many works devoted to this area of research of stochastic systems and networks. They got a lot of interesting results regarding the values of the main characteristics of the operation of the model [312].

Mass-servicing networks with arbitrary service time, in particular under conditions of overload mode of operation, were investigated in works of MI. Mostly open and closed networks with one maintenance device in each node were investigated.

Interesting results from the research of Markov and non-Markov systems and mass-servicing networks with unlimited number of service devices have recently been received by a group of Tomsk scientists. They proposed and developed an approach called the sifted flow method. This method allows the problem of research of the non-Markov system (network) service with an unlimited number of devices for servicing to reduce the problem of the analysis of a non-stationary flow that is marketed. In particular, presents the study of an open-source mass service network with input high-intensity flow requirements called the High Intensivative Markov-Modulated Poisson Process (HIMMPP) with unlimited number of servicing devices in nodes, Markov routing, and recurrent maintenance of requirements in conditions of increasing intensity input stream An asymptotic analysis of this network is carried out. Using the method of dynamically sifted flow for such networks, the authors obtained an expression for calculating the average values of the number of devices employed in the nodes of the described network. It is also established that under the conditions of unlimited increase of the intensity of the input stream, the multidimensional distribution of probabilities of the number of employed devices in the nodes is approximated by a multidimensional normal distribution. In this paper we obtain the characteristics of this distribution in the form of a vector of mathematical expectations and the covariance matrix.

The basic approaches to the study of mass service networks are based either on the direct method of finding expressions for the probabilities of the network conditions using the technique of constructing equations of the local balance, or on the method of constructing recurrent equations for the mean values. The above methods allow us to find the exact solution for multiplicative or, as they are often called, locally balanced networks, the stationary probabilities of states of which have a multiplicative form.

Jackson, Gordon, Newel [313], began to study the simplest homogeneous exponential networks. For these networks, such an interesting fact was established: the stationary probabilities of the network states have a multiplicative form: in the stationary mode, the distribution of the number of requirements at the nodes of the network is independent, and their product is the stationary distribution of the entire network. This fact became the basis for further analyzes of the future of the MEMO of the general type, as well as the development of effective algorithms for the calculation of the characteristics of stochastic networks [314].

The search for the conditions for the existence of a multiplicative form of stationary distribution and in the last decades is reduced mainly to operation with the local equilibrium equation. This leads to the expansion of known results on a more general-looking network. The disciplines of service are generalized, depending on the intensity of the input stream from the state of the network and / or time, etc. In recent years, a number of results have been obtained, which greatly expands the possibilities of analysis of mass service networks. The main methods of analysis, which today are rather complete character, are distinguished. Here are some basic research methods.

The Martingual approach based on the semimartingal representation of the investigated process and the use of a well-developed apparatus for the theory of martingales for the diffusion approximation of service networks, for solving filtration and optimal control problems, and also for statistical analysis of networks.

The recurrence approach, which consists in the recurrence relations for the characteristics of the system under consideration, and for the further asymptotic analysis, the boundary theorems on the convergence of stochastic recurrence schemes to the solution of stochastic differential equations (SDE). This method is used to study a wide class of service systems with repeated calls and in the study of local area networks with multiple access protocols. VV Anisimov introduced a class of random switching processes, which is a convenient means for describing the asymptotic behavior of a broad class of stochastic models. The switching process, the author calls the service process, which can be represented as a semi-Markov process. As a rule, the random environment in which the service model operates is considered as an external process, which is not influenced by the behavior of internal processes. The theorems of the type of the principle of averaging and diffusion approximation are proved in [309], and some classes of systems and mass service networks that can be represented by switching processes are considered. Asymptotic behavior has been investigated for these models, in particular under conditions of low-intensity input flows and under over-mode conditions.

The method of diffusion approximation in work [315] is used for analysis in the conditions of high load of open models of computer networks with arbitrary interval distributions between the moments of receipt of requirements to the network and the duration of their service. In this paper, common closed exponential stochastic networks are also investigated, when the number of requirements in them indefinitely increases. For such networks, conditions for congestion are formulated, in which the proposed deterministic and Gaussian approximations for the process of queue lengths are proposed. The authors managed to obtain an asymptotic schedule for the main indicators of the functioning of the networks.

Non-stationary mass service systems (SMO) also studied in works A.I. Seyman, who describes the process of serving claims in terms of birth and death processes and examining the SMO with the help of an advanced device for these processes. The proposed method is based on the logarithmic norm of the linear operator and the special transformation of the cut-off matrix of intensities of the Markov chain under consideration. This method is applicable to the class of Markovian SMO. In particular, is devoted to the estimation of the convergence velocity for different types of inhomogeneous Poisson flows with a specific form of heterogeneity. Namely, when the intensity of birth and death (the intensity of the input flow and service) is asymptotically periodic functions of time [316].

The given different approaches allow the experts to choose from them the most convenient and effective in a concrete situation. The data of numerical and simulation modeling of networks demonstrate the fact that the results of approximative formulas are quite close to precise with a sufficiently large load.

In the classical theory of mass maintenance, there are not too many models whose research can be performed analytically and obtain final results in the form of formulas for probability-time characteristics of the SMO. These are primarily systems whose processes of changing states are described by the Markov process with a set of states. Semi-Markov systems, which can be used to analyze the method of the embedded Markov chains, are also included here. As an example, we can recall the formula of the Polachek-Hinchin system $M\,|\,G\,|\,1$. Erlang's formulas are also known for N - channel systems with arbitrary distribution of service time and stationary Poisson input flow, the process of changing the states of which is non-Markov.

At the same time, a large number of studies of real systems in various subject areas, in particular telecommunication systems, economic systems, made it possible to conclude that the essential inadequacy of the Markov models is real data. Research of real complex systems is carried out, as a rule, by numerical methods or by means of simulation modeling with all the disadvantages arising from these methods.

An alternative approach is the use of the asymptotic analysis method for the study of complex systems.

Different variants of asymptotic conditions are considered: the maximum interval of observation, the small or high intensity of service, the large delay of requirements in the source of recurring calls, the heavy load in models of real computer networks controlled by random multiple access protocols [317].

Asymptotic methods in the theory of mass service, as a rule, are understood by three following directions of research, the main purpose of which is the study of complex multidimensional servicing processes by approximating their processes with a simpler structure.

1. Asymptotic analysis of explicit formulas or equations describing the distribution (usually stationary) of one or another system characteristic. Since today the theory of mass service has exhausted almost all cases of "explicit solvability" of service systems, the search for other areas of asymptotic analysis is becoming relevant.

2. The second direction is much wider and related to the study of the limiting behavior of the most random processes describing the work of the system, when converging the system with some of its critical state. In the work of [317] shows that the basis of the phenomena arising in overloaded systems lies in the well-known principle of invariance. This principle allows using the Wiener process to describe relatively complex processes generated by sums of random variables.

The main objective of the second direction is to prove the boundary theorems and to identify the maximum general conditions under which their statements will be valid (for example, the convergence of the normalized queue length to the diffusion process). The methods in this direction obviously differ significantly from the methods in §1 and are based, as a rule, on the use of general functional boundary theorems for random processes [318].

3. The third direction is connected with the theorems of stability (or continuity). Essentially, the boundary theorems for processes are also considered here: the conditions under which service systems will be close (in the sense of the distribution of a process describing the system) are set to a given system. The term "stability" is due to the fact that this type of theorem allows us to draw conclusions about small changes in stationary characteristics with small disturbances of the system parameters.

Often, the three classes of processes serve as limitations:

- Gaussian processes;
- diffusion processes;
- processes with independent growth.

In this paper, we will use multidimensional Gaussian processes to construct approximative processes for the requirements processing process in stochastic networks of different types.

The main problems that are considered in the dissertation are related to the approximation of some random processes that arise in the study of stochastic networks, with the help of others - simpler and better investigated. In this case, it is necessary to formalize which processes will be considered close. Naturally, in different tasks, the requirements for proximity can be different.

The concept of convergence of random processes is the basis for using the methods of the theory of random processes in problems of asymptotic analysis of various characteristics of mass service networks. Let's consider different approaches to the formalization of the concept of convergence of random processes. (see, for example [319] Let given sequence of processes $\xi^{(n)}(t,\omega)$ that process $\xi^{(0)}(t,\omega)$. A well-known notion of the convergence of random processes is the weak convergence of finite-dimensional distributions $\xi^{(n)}(t,\omega)$ to the corresponding distributions $\xi^{(0)}(t,\omega)$:

$$P\left\{\xi^{(n)}(t_j,\omega) \le x_j; j=1,...,k\right\} \underset{n\to\infty}{\to} P\left\{\xi^{(0)}(t_j,\omega) \le x_j; j=1,...,k\right\}$$

to all k, $t_1,...,t_k$ and $x_1,...,x_k$ such that

$$P\left\{\xi^{(0)}(t_j,\omega) = x_j\right\} = 0, \qquad j=1,...,k.$$

Such a convergence is indicated

$$\xi^{(n)}(.)\overset{d}{\Rightarrow}\xi^{(0)}(.)\,.$$

Symbol $\overset{d}{\Rightarrow}$ it is also stored to indicate a weak convergence of distributions of random variables (convergence at the points of continuity of the boundary distribution function).

As is known, the weak convergence of finite-dimensional distributions does not imply a convergence of characteristics, determined by the behavior of the trajectory in general, that is, different functionalities $f\left(\xi^{(n)}\right)$ from the process $\xi^{(n)}(t)$ (for example, the average length of the queue $\frac{1}{T}\int_0^T \xi^{(n)}(t)dt$, value of maximum queue $\sup_{0\le t\le T}\xi^{(n)}(t)$). To do this, some additional conditions associated with a fairly regular behavior of the trajectories of processes must be met. $\xi^{(n)}(t)$ [320].

Consequently, the determination of the convergence of processes in general depends on the distribution of which of the functionals $f\left(\xi^{(n)}\right)$ we want to get closer to distributions $f\left(\xi^{(0)}\right)$.

Different approaches to the study of the conditions for the convergence of functionals from random processes were developed in the works [321].

In the works of M. Donsker and Yu.V. Prokhorov studied the boundary behavior of functional distributions from processes constructed on the sums of independent random variables. It was assumed that the functionals are continuous in the topology of uniform convergence, and the boundary process is the process of Brownian motion. It was argued that the desired boundary distribution coincides with the distribution of the same functional from the process of Brownian motion. Statements of this kind have been called "principle of invariance".

In [322] has published a number of papers in which the general problems concerning the boundary behavior of functional distributions from random processes are solved and solved. Abandoned the condition of the continuity of processes and considered the natural class in the theory of probabilities of processes that do not have breaks of the second kind. As a result, the topology of uniform convergence in the space of such functions has to be replaced by a new one, since space becomes inseparable. They introduced a new topology in the space of functions without ruptures of the second kind, which now carries the name of the author. Considering the class of continuous functions in this topology of functions from the sequence of random processes, we establish necessary and sufficient conditions under which the boundary of the distribution of the functional under consideration exists and coincides with the distribution of the same functionality from the boundary process. These general theorems have been applied to specific classes of processes: processes with independent increments, Markovian and Gaussian processes [323].

So let it go X – complete metric separable space with metric $\rho(x,y)$, B_X – σ-algebra of Borel subsets in it, $\xi^{(n)}(t)$, $0 \le t \le T$, $n \ge 1$, – sequence of random processes with values in X. We will assume that the sample trajectories $\xi^{(n)}(t)$ at each one n with probability 1 belong to the set of functions $D_{[0,T]}(X)$, which have no breaks of the second kind and continuous business (at the point T – to the left) [324].

Let $F_S(B)$ – set of functionals given in space $D_{[0,T]}(X)$, measurable relative σ-algebras of cylindrical sets $\mathrm{B}_{D_{[0,T]}(X)}$, and continuous with respect to some type of convergence (let's say S- convergence) on a set of functions B. This means that if the sequence of functions $x_n(\cdot)$ з $D_{[0,T]}(X)$ S- coincides with $x_0(.)$ and $x_0(.) \in B$, then

$$\lim_{n\to\infty} f\left(x_n(t)\right) = f\left(x_0(t)\right). \quad (1.1)$$

For a sequence of random processes $\xi^{(n)}(t)$, $t \ge 0$, such that $\xi^{(n)}(t) \overset{\text{сл}}{\Rightarrow} \xi^{(0)}(t)$, $t \in Q$, where Q – it is somewhere dense set of points on everywhere $[0,T]$, containing points 0 and T, with a weak convergence of measures μ_n, generated $\xi^{(n)}(t)$ in space $D_{[0,T]}(X)$ with some metric h such that is appropriate to her σ- algebra of Borel sets is contained in σ- algebra of cylindrical sets follows $f\left(\xi^{(n)}(\cdot)\right) \overset{\text{сл}}{\Rightarrow} f\left(\xi^{(0)}(\cdot)\right)$, where $f(\cdot)$ – any limited and continuous metric h functional on $D_{[0,T]}(X)$.

In studying the conditions of convergence of classes of functional, continuous with respect to different metrics h, with the use of Prokhorov's theorem we must look for a general form of compact in the corresponding space. In this connection, when studying the conditions of convergence of specific functionals, it is sometimes more convenient to use constructive probabilistic methods and the method of one probabilistic space developed by [325]. We note that the conditions for convergence for a "certain" functional are given in the work [326].

We give in accordance with [327] the conditions for the convergence of functions that are continuous on the set of functions B relative to some S - convergence. Assume that there is an inseparable monotone non-decreasing in $c>0$ functional $\Delta_S\left(c, x(.)\right)$ such that sequence $x_n(.)$ S - coincides with $x_0(.)$ if and only if the conditions are fulfilled:

$$\lim_{n\to\infty} x_n(t) = x_0(t), \quad t \in Q, \tag{1.2}$$

where Q – some numbered dense set of points on everywhere $[0,T]$, containing points 0 and T;

$$\lim_{c\to+0} \overline{\lim_{n\to\infty}} \Delta_S(c, x_n(.)) = 0. \tag{1.3}$$

These conditions and that $x_0(.) \in B$ enough to fulfill the condition (1.1). [317] introduced five different types of convergence satisfying (1.2), (1.3). For our purposes we confine ourselves to the introduction of uniform convergence (U - convergence), since during the whole work the limiting process has a probability unit of continuous trajectories [328].

Let's put it

$$\rho_U(x(\cdot), y(\cdot)) = \sup_{0\le t\le T} \rho(x(t), y(t)).$$

Sequence $x_n(.)$ called convergent in a uniform topology (U -converging) to $x_0(.)$ on the segment $[0,T]$, if

$$\lim_{n\to\infty} \rho_U(x_n(\cdot), y_n(\cdot)) = 0.$$

Sequence $x_n(.)$ called convergent in J - topology (J-converging) to $x_0(.)$ on the segment $[0,T]$, if there is a sequence of continuous mutually unambiguous mappings $\lambda_n(t)$ on the segment $[0,T]$ on yourself such that

$\lim\limits_{n\to\infty}\sup\limits_{0\le t\le T}\left\{\rho_U\left(x_n(t),x_0(\lambda_n(t))\right)+\left|\lambda_n(t)-t\right|\right\}=0$.

Note that J - Convergence means that you can enter a "small" deformation of time (replacing time using the function $\lambda_n^{-1}(t)$) for a prefetch function $x_n(t)$ in such a way that the moments of the jumps of functions $x_n\left(\lambda_n^{-1}(t)\right)$ and $x_0(t)$, who do not go to 0, coincide, and functions will be close in uniform topology. From the definition it follows that with U - convergence follows J - convergence [329].

By $D^m_{[0,T]}$ we will denote the space of functions with values in $\mathbb{R}^m$ without breaks of the second kind and continuous business (at the point T – left). Sequence of functions $x_n(t)$ whith $D^r_{[0,T]}$ called convergent in a uniform topology (U-converging) to $x_0(t)$ on the segment $[0,T]$, if

$$\lim_{n\to\infty}\sup_{0\le t\le T}\left|x_n(t)-x_0(t)\right|=0$$

($|a|=\sqrt{\sum\limits_{k=1}^{m}a_k^2}$ – the norm of the vector $a'=(a_1,...,a_r)$).

The conditions of convergence can be described in terms of the sequence itself, using the concept of the continuity module [330].

Let's denote $t_c=\max(0,t-c)$, $t^c=\min(T,t+c)$. Let's put it

$$\Delta_U(c,t,x(.))=\sup\left\{\rho\left(x(t),x(t_1)\right):\ \ t_c+{}^{c}\!/_{2}\le t_1\le t^c-{}^{c}\!/_{2}\right\};$$

$$\Delta_J(c,t,x(.))=\sup\left\{\min\left(\rho\left(x(t),x(t_1)\right),\rho\left(x(t),x(t_2)\right)\right):\ \ t_c<t_1<t<t_2<t^c\right\},$$

Let's denote through S one of the topologies U, J. Let's put it

$$\Delta_S(c,x(.))=\sup_{0\le t\le T}\Delta_S(c,t,x(.)).$$

In [331] it is shown that the introduced topologies satisfy the conditions (1.2), (1.3).

For functionals from random processes, the conditions of weak convergence look like this.

In order for any functional $f(\cdot) \in F_S(B)$ distribution $f\left(\xi^{(n)}(.)\right)$ weakly coincided with the distribution $f\left(\xi^{(0)}(.)\right)$, enough to

1) $$\xi^{(n)}(t) \overset{d}{\Rightarrow} \xi^{(0)}(t), \;\; t \in Q,$$

where Q – a number of dense sets of points on everywhere $[0,T]$, containing points 0 and T;

2) for any one $\varepsilon > 0$

$$\lim_{c \to +0} \overline{\lim_{n \to \infty}} P\left\{\Delta_S(c, \xi^{(n)}(.)) > \varepsilon\right\} = 0;$$

$$P\left\{\xi^{(0)}(\cdot) \in B\right\} = 1.$$

In the future, if the two last conditions are fulfilled, we will say that the sequence $\xi^{(n)}(\cdot)$ S - coincides with $\xi^{(0)}(\cdot)$.

Note that a uniform topology is commonly used in the study of convergence to continuous functions. If the boundary function is discontinuous, then U - convergence can occur only in cases where for any $\varepsilon > 0$ starting with some n moments of jumps larger than ε, coincide, which in practice occurs quite rarely [332].

As can be seen from the above, the variable intensity of the input flow requirements is much closer to real networks, but the intensity dependence of time adds additional difficulties in the study of the corresponding models. The analysis of such systems and mass-servicing networks is a complex mathematical task. At the same time, despite the fact that some published materials contain studies of mass service systems with variable parameters, there is still no general methodology for researching such models. In general, stochastic networks with variable characteristics have been studied very little.

One of the approaches that may be promising in this area of research is the use of asymptotic methods such as Gaussian or diffusion approximation. This approach is developed in this dissertation. It examines the behavior of the requirements servicing process in multichannel networks of the Markov and Semi Markov type, in which the input flow parameters depend on time and fulfill the critical loading conditions. Models of stochastic networks described in the dissertation are quite close to real information and computer networks and communication networks. From the systems of mass service they are distinguished, first of all, by the multidimensionality of the service process and the complex structure of the input stream for each service node of the network [333].

In the work for multichannel stochastic networks with variable external load, asymptotic research methods based on the approximation of the hopping processes of service requirements by continuous Gaussian and diffusion processes were proposed. In particular, the network with periodic and asymptotically periodic external input flow requirements is considered. In the case when network maintenance is not index-distributed, a phase-in-service case is distinguished. It is shown that by increasing the number of service nodes and the dimensionality of the phase space, it reduces to the Markov stochastic network.