Improving the dynamics of information flows for optimizing telecommunication systems

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Abstract. The article considers the problem of optimization of telecommunication systems based on improving the dynamics of information flows. This task is formulated on the basis of a systematic approach, which consists in the fact that a multidimensional indicator is chosen as a system indicator, taking into account not only the connections of elements, but also the degree of use of these connections in the functioning of the network. This allows you to distribute information flows by changing the elements of the route matrix in the model of an open queuing network in order to optimize the system. It is shown that it is expedient to solve the optimization problem by applying the developed algorithm for the general solution of the problem. Algorithm procedures for the dynamics of information flows imply the transfer of part of the load of the elements that are bottlenecks to other elements of the system. The performance of the algorithm is confirmed by an example.

1. Introduction
The modern development of telecommunication systems and networks follows the path of combining the capabilities of public telephone networks, mobile communication systems, data transmission systems and other networks. This requires their coordinated functioning under variable load [1, 2]. Implementation of international 5G standards allows to ensure the specified coordinated functioning by efficient use of available resources. This is achieved by the technological capability provided to network operators to "cut" and transfer the power of 5G networks to counterparties (virtual operators) [3]. The conditions of the dynamics of the load, the resources used and the requirements for the quality of the offered telecommunication services necessitate a more complete coordination of the characteristics of the elements of telecommunication systems (STC) in the distribution of information flows (IF).

However, in the existing STK, the distribution of the IF in each switching node is carried out locally, i.e. without applying a systematic approach. With such a distribution, the IF is distributed over the communication channel with the lowest load, or, at best, the load of the communication channels of the next switching node is additionally taken into account [1, 2]. This principle leads to the fact that the majority of streams can be directed to such communication channels, which will lead in the course of subsequent transmission to the most loaded channels, and, as a consequence, to a deterioration in the performance of the STC. This proves that in highly organized systems, it is the interconnections between the components (and not the components themselves) that determine to a greater extent the qualitative characteristics of integrity [4].
Thus, in the STC of the 5G standard, when distributing IF under dynamic load conditions, it is relevant to use a systematic approach, taking into account the characteristics of the elements and their connections in the system. In this case, it is advisable to describe the STC using a system multidimensional indicator that reflects the degree of use of connections between all components. This article is devoted to the solution of the problem of optimization of the STC on the basis of the system approach in the distribution of IF.

2. Formulation of the problem
In order to formulate this optimization problem in detail, it is advisable to consider its components:
- choice of optimization criterion based on a systematic approach;
- selection of the mathematical model of the STC and its system indicator;
- selection of basic and additional restrictions;
- development of an algorithm for solving the problem;
- verification of the algorithm using computer simulation.

The efficiency of the STC under variable load conditions and dynamics (distribution) of the IP is expedient to evaluate using the costs (economic, time, etc.) for management and implementation, that is, for switching information flows. Then the optimization criterion is the minimum costs for all switching of information flows during the transition of the STC from the initial to the final state.

Taking into account the systematic approach, it is expedient to choose a multidimensional indicator as a systemic indicator that takes into account not only the connections of elements, but also the degree of use of these connections in the functioning of the network. In conditions of continuous monitoring of the performance of modern STC, it is advisable to take the required performance at nominal loads as the main limitations.

Thus, in a meaningful form, the formulation of the optimization problem for the telecommunications system can be formulated as follows. There is a telecommunications system, characterized by the initial values of the parameters and a multidimensional indicator that takes into account not only the connections of the elements, but also the degree of use of these connections in the operation of the network. It is required to optimize the dynamics of information flows in order to minimize costs while achieving the required performance.

3. Theoretical part
Consider the mathematical model of the STC taking into account the systematic approach. For telecommunication systems, the utilization of the potential of available resources can be reflected in the performance assessment. Indeed, from the point of view of ensuring the required performance, in most cases, the optimization of telecommunication systems is performed [1-3]. Moreover, the reactivity index $\bar{t}$ should be chosen as the primary performance index. This integral characteristic (average residence time of a request, demand, fragment of a flow in the network, delay) is the most informative for telecommunication systems [2, 5, 6].

When assessing performance, it is necessary to use the system parameter (and not only the parameters characterizing the elements of the system themselves), reflecting the interaction of the elements during the functioning of the entire system. For telecommunication networks, consideration of the structure is insufficient. Indeed, in addition to taking into account the fact of interaction of elements, it is necessary to know how intensively this connection between elements is used.

To ensure the analysis of systems (networks) of any configuration and with a large number of elements, the model of an open queuing network (OQN) should be used. The theory of OQN was developed as a further development of the theory of queuing systems, including with the aim of removing the restriction on the analysis of systems with a large number of elements. The model of the open OQN allows sequentially using analytical dependencies to calculate the values of the coefficients for unknown members of the system of linear equations, the roots of which are the intensities of the
input flow to the network elements. Further, also using analytical dependencies, the network performance is calculated, specifically the reactivity index $\bar{\eta}$.

To improve the accuracy of the estimate, one can use the second-order theory for OQN, where it is necessary to solve a second time (by pre-calculating the coefficients at unknown terms) a system of linear equations, the roots of which are the values of the coefficients of variation between the arrivals of claims (requests, flow fragments) to the element. Only then, using analytical dependencies, determine the value of network performance $\bar{\eta}$. At the same time, it is advisable to use the second-order UDN (Peoples' Friendship University) algorithm for the OQN when estimating $(\bar{\eta})$, in accordance with the expressions (1) - (12) given below for the open OQN, shown in Figure 1.

![Figure 1. Representation of the analyzed network in the form of an open OQN](image-url)

Open OQN more clearly reflects the processes of telecommunications. In comparison with the results of statistical modeling, the relative error of the characteristics estimated using the UDN algorithm is in the range of (0.3 - 4.7)% [5].

The UDN algorithm is determined by the mapping [5].

$$G : X_1 \rightarrow \mathcal{T}, X_1 = \{M, Q, CB, COA, HO\}, \quad (1)$$

where $\bar{\eta}$ is the network performance, reactivity index;

$M = \{M(i)\}, i = 1, L$ - vector of productivity of network elements (intensities of service by elements of input flows);

$L$ is the number of network elements;

$Q = \{q(i, j)\}, i = 0, L, j = 0, L$ - routing matrix,

$q(i, j)$ is the probability that the claim (requirement) after service in element i will go for service in element $j$. 


\( CB = \{ CB(i) \}, i = 1, L \) - vector of coefficients of variation of the distribution of time intervals between the end of servicing requests (requirements);

\( COA = \{ COA(0, i) \}, i = 1, L \) - vector of coefficients of variation of the distribution of time intervals between the arrival of applications (requirements) to the element from the source of applications;

\( H_0 \) – scalar, intensity of the source of claims.

In this mapping, a routing matrix is used as a system parameter, which reflects the distribution of flows in the network and thereby characterizes the role of each element in the overall functioning of the network.

Due to the ergonomics of the network and the indecomposability of the matrix \( Q \) the vector of intensities of the total flow of applications \( H = \{ H(i) \}, i = 1, L \) in the network elements satisfies the system of equilibrium equations [5]:

\[
H(i) - \sum_{K=1}^{L} H(K) \cdot q(K, i) = H_0 \cdot q(0, i), i = 1, L.
\]

Consider additional variables [5]:

\[
FB(i) = M(i) \left[ CB^2(i) - 1 \right], i = 1, L;
\]

\[
FOA(0, i) = H_0 \cdot q(0, i) \left[ COA^2(i) - 1 \right], i = 1, L;
\]

\[
FA(i) = H(i) \left[ CA^2(i) - 1 \right], i = 1, L;
\]

\[
p(i) = \frac{H(i)}{M(i)}, i = 1, L.
\]

\( FA(i) \) are the roots of a system of linear algebraic equations of the form:

\[
FA(i) - \sum_{K=1}^{L} FA(K) \left[ 1 - p^2(i) \right] \cdot q^2(K, i) = FOA(0, i) + \sum_{K=1}^{L} FB(K) \cdot p^2(i) \cdot q^2(K, i),
\]

\[
i = 1, L
\]

The average waiting time for a request (request) in the element queue \( i, i = 1, L \) is determined by the expression [5]:

\[
W(i) = \frac{p(i)}{2M(i) \cdot [1 - p(i)]} \cdot \left[ CA^2(i) + CB^2(i) \right] \cdot g[p(i), COA(i), CB(i)];
\]

\[
g[p(i), CA(i), CB(i)] = \begin{cases} 
\exp \left( - \frac{2[1 - p(i)]}{3 \cdot p(i)} \frac{1 - CA^2(i)}{CA^2(i) + CB^2(i)} \right) & \text{if } CA(i) \leq 1; \\
\exp \left( -1 \cdot p(i) \frac{CA^2(i) - 1}{CA^2(i) + 4CB^2(i)} \right) & \text{if } CA(i) > 1.
\end{cases}
\]

Average residence time of a request in an element \( T = 1, L \):

\[
V(i) = W(i) + \frac{1}{M(i)}.
\]

Let us define the parameter reflecting the “share” of the participation of the network element in servicing the input stream \( H_0 \):
5

Then the reactivity index is determined:

$$ A(i) = \frac{H(i)}{H_0} $$

(11)

Then the reactivity index is determined:

$$ T = \sum_{i=1}^{L} A(i) \cdot V(i). $$

(12)

4. Formalization of the optimization problem

To formalize the optimization tasks, it should be taken into account that the G1 (1) mapping allows you to use not only the connections of elements, but also the degree of use of this connection in the operation of the network. This is ensured by the fact that the routing matrix \( Q \) is included in the display sending area G1, which is a kind of "system" parameter. Therefore, the values of the elements of the routing matrix \( q(i, j), i=0,L; j=0,L \) should be used as the control (variable) parameters in the formulated problem of optimization of telecommunication systems.

Let's formulate the problem in a formalized form.

The following initial data is given.

1. Initial state of the telecommunications system ensuring performance \( t_0 \):

   \[ XO = \{M, QO, CB, COA, HO\}. \]

   (13)

2. G1: \( X \rightarrow \tilde{t} \) - display by performance evaluation.

3. Mapping on the estimated costs \( C \) required for implementation of \( \Delta Q \)

   \[ G2: \Delta Q \rightarrow \tilde{C}. \]

(14)

where \( \Delta Q = [\Delta q(i, j)], i=0,L; j=0,L \);

\( \Delta q(i, j) \) - changes (costs) \( q(i, j) \), providing the dynamics of information flows.

It is required to find the minimum cost

\[ C(\Delta Q) \rightarrow \text{min}. \]

(15)

Consider the following restrictions.

1. Main limitation

\[ \tilde{t} \leq \tilde{t}_T. \]

(16)

where \( \tilde{t}_T \) - the required value of the performance of the telecommunications system, which is achieved as a result of the dynamics of information flows.

2. Additional restrictions:

- cost limitation

\[ [q(i, j)]_{\text{min}} \leq q(i, j) \leq [q(i, j)]_{\text{max}}, i=0,L; j=0,L. \]

(17)

- the condition for ensuring the stationary operation of OQN

\[ \rho(i) < 1, i=0,L. \]

(18)

- the condition for ensuring "stochasticity" \( Q \), the sum of the elements in the matrix row is equal to 1 (the condition for the full group of events)

\[ \sum_{j=0}^{L} q(i, j) = 1, i=0,L. \]

(19)
Consider the case when the costs of changing any element $Q$ are the same and the cost function has a linear relationship

$$C = c_0 \left[ \sum_{i=0}^{L} \sum_{j=0}^{L} \Delta q(i, j) \right],$$

(20)

where $c_0$ is the cost of the element of the routing matrix.

The general algorithm for solving the problem of optimizing the communication system is shown in Figure 2.

**Figure 2.** Algorithm for the general solution of the STC optimization problem

For case (20), the minimum cost $C$ is provided by the minimum sum of changes in the elements of the routing matrix, and the problem is formulated as achieving the required performance (or the smallest delay value under existing constraints) with minimal total changes in the elements of the routing matrix. Therefore, knowing the value of $c_0$ is optional. In such conditions, the task of optimizing telecommunications systems based on improving the dynamics of information flows can be solved by performing a sequence of procedures in accordance with the algorithm for the general solution of the optimization problem (see Figure 2).

The following comments can be given to the algorithm for the general solution of the optimization problem for telecommunication systems.
1. Login. Beginning of the procedures for solving the optimization problem.
2. Input of initial data.
3. Determination of bottlenecks (BN), system elements that are most loaded in the initial state of the system.
4. Redistribution of information flows to "unload" the BN, that is, in the course of the dynamics of information flows, part of the load of the elements that are BN, is transferred to other elements of the system. It is the unloading of the BN that ensures minimal changes in the elements of the routing matrix. If you unload elements that are not BN, then this will require not only large changes in the elements of the routing matrix, but also in significant cases, may even lead to a deterioration in performance.
5. Check the fulfillment of the condition, has the required performance been achieved after the redistribution of information flows during the unloading of certain BN’s? If YES, then go to item 8, if NO, then go to item 6. This condition checks the fulfillment of the main constraint (16).
6. Check the fulfillment of the condition, are the ranges of changes in the elements of the routing matrix exhausted? If YES, then go to item 7, if NO, then go to item 3. This condition clarifies the possibility of changing the elements of the routing matrix in accordance with additional constraints (17) - (19).
7. The required performance of the telecommunications system by the dynamics of information flows under the specified constraints is not achievable. In this case, the solution to the problem is to consider the state of the system that provides the minimum possible value of performance achieved during the execution of procedures 4.
8. Conclusion of the results of solving the problem of optimization of the telecommunications system.
9. Exit. Completion of procedures for solving the optimization problem.

It is necessary to clarify the question of determining the BN. There is a known method for diagnosing bottlenecks (BN) of the system (production processes) [7], involving the identification of BN by visual observation of the production process with the specification of the following characteristics:
- the highest load of the element - BN (the ratio of the intensity of service to the intensity of the input flow);
- the smallest capacity, the volume of production is limited by the capabilities of the BN;
- equipment and personnel are fully loaded into BN;
- queues and jams of parts, semi-finished products, etc. for processing (service) in the BN.

Also in [7] it is argued that production capacity depends on the structure of production processes and that you should take care of the compliance of production processes with the structure of products. However, the procedure for accounting for dependencies and ensuring compliance is not provided.

The method for diagnosing the BN considered in the article [8] makes it possible to identify the BN in the architecture of local networks, as well as the shortcomings of the applied software (software), which result in inefficient use of the server and network bandwidth. It is supposed to use software protocol analyzers for diagnostics, for example, Observer from Network Instruments. The utilization of network elements is measured - the degree (share) of the use of a resource, an element. If the utilization of an element (resource) exceeds the permissible value, then this element (resource) is a BN. The definition and influence of the BN on the overall performance of the network is only stated by the statement that due to the BN, the network bandwidth turns out to be inadequately low. The practical ability to analyze systems (networks) with a large number of elements and (or) with any arbitrary configuration is not considered.

The indicated disadvantages of the previously considered methods are partially eliminated in work [9], where it is shown that the use of the queuing systems (QS) apparatus in the analysis of business processes allows solving the problem of BN analysis, determining the average number of servicing devices, the load of QS elements and the average residence time claims in the network (i.e. network performance). BN is created by a node, in which the load factor approaches one. In the course of the experiment, statistics are generated on the proposed model of the multi-agent resource conversion process, the accounting of which provides the diagnostics of the BN. Despite the fact that the QS
apparatus provides the ability to analyze systems of any configuration, at the same time, it limits the analysis of systems with a large number of elements.

Unlike the method for diagnosing the BN considered in [9], the method for diagnosing the BN is proposed in the article [10], although, like the previous ones, they search for the BN by the criterion of loading elements, but it shows how, without resorting to modeling, using the operational analysis of probabilistic QS you can get the calculated characteristics at the level of average values.

The logical result of the analysis of the methods for determining the BN is that the load of the system element is an indicator of the BN. In the OQN model considered in the article, the mapping $G_1$ in the course of determining the performance calculates the load of the system elements (as the ratio of the input flow rate to the service rate). In the example considered below, an algorithm for the general solution of the problem of optimizing a telecommunications system is applied, while the BN is determined by the value of the load of the elements.

5. Simulation results

Consider an example that illustrates the practical significance of the proposed approach.

Example. Consider a telecommunications system consisting of 15 elements ($L=15$). The intensity of the source $H^0=2 \text{ message/s}$, $0 \leq q(i, j) \leq 1$, $i=0, L$, $j=0, L$. The rest of the initial data are shown in Table 1.

Table 1. Initial data of the example

| Parameters | Item number |
|------------|-------------|
| $M(i)$ [$\text{message/s}$] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.5 | 4.5 | 4.5 | 4.0 | 4.0 | 4.0 | 2.0 | 2.0 | 2.0 |
| $CB(i)$ | 0.3 | 0.3 | 0.3 | 0.7 | 0.7 | 0.7 | 1.2 | 1.2 | 1.5 | 1.5 | 1.5 | 0.8 | 0.8 | 0.8 |
| $COA(i)$ | 0.7 | 0.8 | 0.9 | - | - | - | - | - | - | - | - | - | - | - |

The initial routing matrix $Q_0$ is represented in Table 2.

Table 2. Initial routing matrix $Q_0$

| i | j | 0 | 0.25 | 0.30 | 0.45 |
|---|---|---|---|---|---|
| 0 | 0.40 | 0.40 | 0.20 |
| 1 | 0.30 | 0.50 | 0.20 |
| 2 | 0.40 | 0.30 | 0.30 |
| 3 | 0.30 | 0.70 |
| 4 | 0.40 | 0.60 |
| 5 | 0.50 | 0.50 |
| 6 | 0.20 | 0.30 | 0.50 |
| 7 | 0.25 | 0.35 | 0.40 |
| 8 | 0.20 | 0.40 | 0.40 |
| 9 | 0.60 | 0.40 |
| 10 | 0.50 | 0.50 |
| 11 | 0.40 | 0.60 |
| 12 | 1.00 |
| 13 |
| 14 |
| 15 | 1.00 |
The cost function is determined by expression (20). In this case, the costs will be determined by the total changes in the elements of the routing matrix 
\[ \sum_{i=0}^{L} \sum_{j=0}^{L} |\Delta q(i,j)| \] and the cost function can be conditionally expressed by this amount. As a result of the analysis of the initial data and taking into account the procedures specified in paragraph 4 of the general algorithm, the example condition is the following condition.

It is required to optimize the dynamics of information flows while ensuring the fulfillment of the main constraint (16), that is, achieving the required system performance \( \hat{t}_T = 8.40 \).tsT  8,40 .

**Decision.** In the course of determining the performance of the system, corresponding to the initial data, using expressions (1) - (12), the results indicated in Table 3 were obtained, which provides: \( \hat{t}_0 = 8.90 \).0ts  8,90 .

Since \( \hat{t}_0 = 8.90 > \hat{t}_T = 8.40 \), we determine the BN by analyzing the loading of elements. BN with the initial data of the example are elements 3 and 9 (see table. 3):

\[ \rho(3) = 0.75; \quad \rho(9) = 0.69. \]

Therefore, by unloading elements 3 and 9, you can ensure a fuller use of the potential capabilities of the system.

Let us consider separately the procedures for changing the elements of the routing matrix by unloading element 9.

The unloading of element 9 is provided by decreasing the value \( q(12,9) = 0.60 \). Suppose the step of discretion of change is 0.12. Then

\[ q(12,9) - 0.12 = 0.60 - 0.12 = 0.48. \] \( q(12,9) - 0.12 = 0.60 - 0.12 = 0.48. \) (21)

At the same time, to provide additional constraint (18), we change the values of the route matrix element in row 12

\[ q(12,7) + 0.12 = 0 + 0.12 = 0.12. \] \( q(12,7) + 0.12 = 0 + 0.12 = 0.12. \) (22)

That is, element 9 is unloaded by element 7. It is element 7 that has a low load value, as shown in table 3.

### Table 3. Results of solving the example

| Parameters | Item number |
|------------|-------------|
|            | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| \( H(i) \) | 1.25 | 2.00 | 2.25 | 1.38 | 2.02 | 1.46 | 1.67 | 2.36 | 3.09 | 1.46 | 2.04 | 1.96 | 0.83 | 0.94 | 1.23 |
| \( \rho(i) \) | 0.42 | 0.67 | 0.75 | 0.46 | 0.67 | 0.49 | 0.37 | 0.53 | 0.69 | 0.37 | 0.51 | 0.49 | 0.42 | 0.47 | 0.62 |

Consider the following during the procedures performed. Elements 7 and 9 interact not only with elements 12, but also with others, either directly or through other elements. Therefore, in order to reduce the effect of overshoot, it is necessary to return the flow transmitted to element 7 from the input of element 9, at least partially, to the previous routes. This must be done so that the unloading of the element 9 and the additional load of the element 7 touch mainly only these elements.

Returning flows to the previous routes is done as follows:
\[ q(7,12) + 0.06 = 0 + 0.06 = 0.06; \]
\[ q(7,10) - 0.06 = 0.30 - 0.06 = 0.24. \]

The change value of 0.06 is selected on the basis of 0.5 step of discreteness of changes in (21), (22). First, it should be remembered that improving system performance is achieved by changes (21), (22). Secondly, you can choose as a variable probability \( q(7,1) = 0.20 \).

Load \( \rho(7) = 0.42 \), \( \rho(10) = 0.37 \), so reducing \( q(7,1) \) of 0.06 will lead to a larger overshoot than a decrease in \( q(7,10) \).

We carry out changes in the unloading of element 3 with similar justifications.

\[ q(6,3) - 0.12 = 0.50 - 0.12 = 0.38; \] \[ q(6,1) + 0.12 = 0 + 0.12 = 0.12; \]
\[ q(1,6) + 0.06 = 0 + 0.06 = 0.06; \]
\[ q(1,4) - 0.06 = 0.40 - 0.06 = 0.34. \]

Expressions (25) - (26) reflect changes in the 6th row, and expressions (27) - (28) - changes in 1 row of the routing matrix.

The total changes in the elements of the routing matrix are determined by the terms in expressions (21) - (28).

\[ \sum_{i=0}^{5} \sum_{j=0}^{5} |\Delta q(i,j)| = 0.12 + 0.12 + 0.06 + 0.06 + 0.12 + 0.12 + 0.06 = 0.72. \]

Cost function \( C = c_0 * 0.72 \).

As a result of changes (21) - (28), we obtain the routing matrix \( Q_1 \) presented in Table 4, while ensuring the required performance

\[ \hat{t}_0 = 8.36s < \hat{t}_T = 8.40s. \]

The problem has been solved.

| Table 4. Route matrix \( Q_1 \) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|   | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| i  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 0.25 | 0.30 | 0.45 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0.4 | 0.34 | 0.06 | 0.20 |   |   |   |   |   |   |   |   |   |   |   |   |
| 2  | 0.3 | 0.5 | 0.30 | 0.30 |   |   |   |   |   |   |   |   |   |   |   |   |
| 3  | 0.4 | 0.30 | 0.30 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 4  | 0.30 | 0.40 | 0.70 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 5  | 0.40 | 0.60 | 0.06 | 0.50 |   |   |   |   |   |   |   |   |   |   |   |   |
| 6  | 0.12 | 0.38 | 0.24 | 0.50 | 0.24 | 0.06 | 0.50 |   |   |   |   |   |   |   |   |   |
| 7  | 0.20 | 0.06 | 0.35 | 0.40 | 0.35 | 0.40 | 0.40 |   |   |   |   |   |   |   |   |   |
| 8  | 0.25 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |   |   |   |   |   |   |   |   |   |
| 9  | 0.20 | 0.60 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |   |   |   |   |   |   |   |   |   |
| 10 | 0.5 | 0.12 | 0.48 | 0.48 | 0.12 | 0.48 | 0.48 |   |   |   |   |   |   |   |   |   |
| 11 | 0.5 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |   |   |   |   |   |   |   |   |   |
| 12 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |   |   |   |   |   |   |   |   |   |
| 13 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |   |   |   |   |   |   |   |   |   |
| 14 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |   |   |   |   |   |   |   |   |   |
| 15 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |   |   |   |   |   |   |   |   |   |

The practical significance of the study lies in the fact that solving the formulated problem of optimizing 5G telecommunications systems by distributing information flows under dynamic load conditions allows finding bottlenecks in the system, avoiding them and minimizing management costs while ensuring the required performance.
6. Conclusions

1. In telecommunication systems of the 5G standard, under conditions of load dynamics, resources used and strict requirements for the quality of services offered, it is advisable to use a systematic approach to more fully harmonize the characteristics of system elements when distributing information flows.

2. The systemic approach is that a multidimensional indicator is chosen as a system indicator, which takes into account not only the connections of elements, but also the degree of use of these connections in the functioning of the network. This allows you to distribute information flows by changing the elements of the routing matrix in the model of the open OQN in order to optimize the system.

3. The task of optimizing the telecommunication system for case (20) based on improving the dynamics of information flows should be formulated as the task of achieving the required performance (or the smallest delay value under existing constraints) with minimal total changes in the elements of the routing matrix.

4. It is advisable to solve the posed optimization problem by applying the developed algorithm for the general solution of the problem. Algorithm procedures for the dynamics of information flows imply the transfer of a part of the load of elements that are bottlenecks to other elements of the system. The performance of the algorithm is confirmed by an example.

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