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The intelligent service control efficiency evaluation method

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Abstract: intelligent service control efficiency appraisal criterion is proposed. By building of the criterion into consideration are taken, besides technical and economical characteristics, also the character of the incoming flow and the degree of the user satisfaction of the service quality. There is presented an example of the proposed criterion calculation for the centralized and decentralized principle of intelligent service control in the next generation networks.

Keywords: *intelligent service; next generation networks; quality criterion; service quality; decentralized principle; centralized principle.*

Actuality. For the first time the notion of the "intelligent service" and the "intelligent superstructure" was introduced in 1990 in the intelligent networks. The intelligent networks conception wasn't able to guarantee the necessary diversity of services and it hasn't gained the development which was predicted to it [2], but it laid the basis for the intelligent services support which services afterwards were used at the next stage of telecommunication network development – the next generation networks (NGN – Next Generation Networks).

Intelligent services (IS) are called services which are rendered to the customer by the help of the special devices – an intelligent superstructure. The first such service of this kind in the 70's in the USA has become the service Freephone or service "800" as it was also called.

At the present moment the IS-list has grown considerably, there have appeared such services as: Premium Rate Service (the calls with adding of an additional payment, for example, for an access to the informational resources or for taking part at the telephone lotteries, voting and suchlike), Prepaid Calling (prepaid calls with an access of the customers according to the passwords), Least Cost Routing (the forwarding by the most profitable route), VAS (Value Added Services) and a variety of other services.

Outgoing of the report delivered by the National commission which performs state regulation in the sphere of communication and informational support of Ukraine, during 9 months of 2016 (table 1) [7], one can observe the immense tempo of the income increasing from IS-rendering. The incomes from rendering of the "Other services" in which the IS-incomes are included have increased 657,9 million UAH in comparison with the same period of the last year, and their relative share has increased 2,7% (Fig.1). The demand for IS is increasing drastically, and it signifies that the questions of the IS-control efficiency are becoming more and more actual.

Table 1. Rendering communication services incomes for 9 months of 2015-2016 years.

	Communication services rendering incomes		Tempos of increasing (decreasing), %	The incomes relative share in the general income value of communication, %	
	9 months of 2015 year	9 months of 2016 year		9 months of 2015 year	9 months of 2016 year
Incomes – total, including:	**41377,3**	**45568,4**	**110,1**	**100,0**	**100,0**
Telecommunication services	37052,4	39203,8	105,8	89,6	86,1
Post communication services	2867,4	3525,3	122,9	6,9	7,7
Other services	1457,5	2839,3	194,8	3,5	6,2

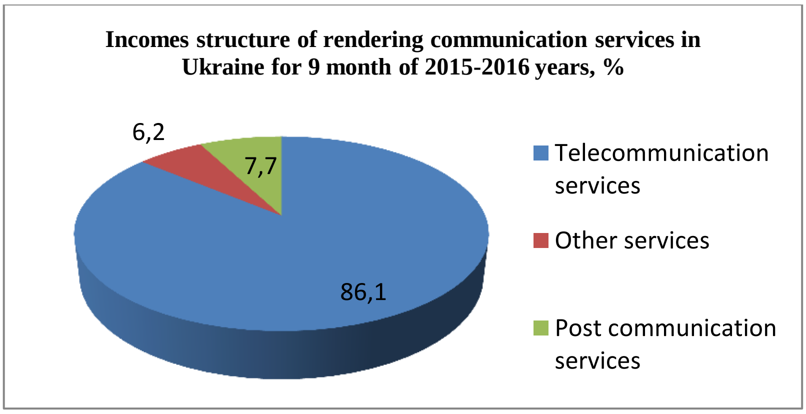

Fig. 1. Incomes of communication services rendering (millions of UAH)

Publications analysis. The questions connected with IS-control efficiency valuation methods research are discussed in publications of V.Steklov, L.Berkman [9], N.Kniaseva [5, 6], S.Shestopalov [13]. In the publications [5, 13] the control device is considered as mass service system – MSS (by centralized control principle) or as mass service network MSN (by decentralized or mixed control principles).The arriving flows of orders for services are considered as exponential ones. But in the result of using of exponential models the received MSS (MSN) characteristics appear more optimistic than characteristics of real networks because the flows in the real networks possess properties of self-similarity.

The problem definition. Among the questions dedicated to the transition to NGN on of the most important and actual is the question of evaluation of efficient control of IS in NGN. The IS-control efficiency evaluation is connected with the network architecture analysis, with the control system building principle and with the IS-control efficiency resulting criterion development.

At the present stage of NGN conception development there is used an intelligent superstructure with centralized control principle (ISCCP). The network with such architecture is presented in Fig.2 [5].

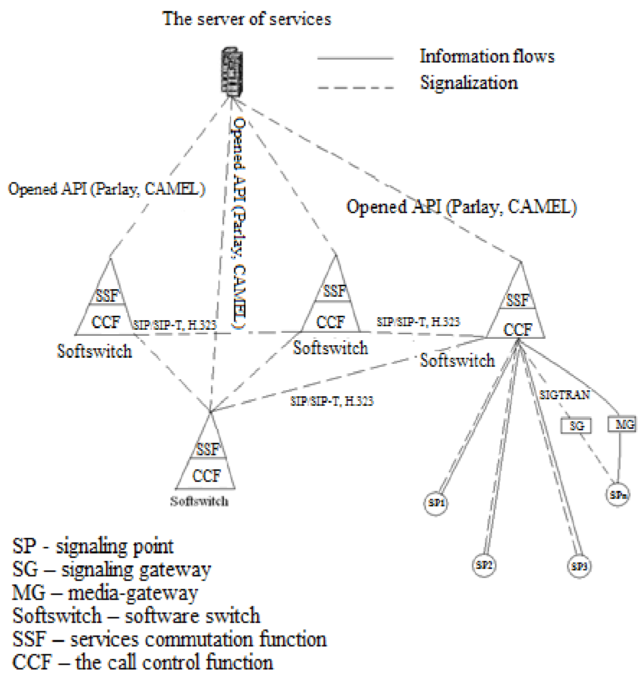

Fig. 2. NGN architecture with ISCCP

In the general case ISCCP contains only one control center (services server). On this server there are all necessary data for performance of service of order on IS.

But in some cases the utilization of ISCCP leads to the following:

1. There can appear a problem connected with the limited pass-through capacity of the signalization network and with the limited services control centers capacity.

2. There exist the kinds of services which according to their properties are not intended for the centralized performance. These are services in which a great pass-through capacity of the signalization network is needed.

3. There exists a variety of services which demand an immediate processing.

A solution of these problems may be the use of intelligent superstructure with decentralized control principle (ISDCP). The ISDCP network is presented in the Fig.3 [13].

In ISDCP are present several commutation services nodes (the program commutator) and several rendering services control nodes (servers). Two approaches to ISDCP functioning can be discussed [4]. In the first approach every server contains servicing logic of all classes of services (universal server). The second approach involves using of specialized servers (a server contains the service logic only for some definite service classes). There can be also provided the possibility of delivering services of a certain class on several servers for the case of breakdown of every server.

For the efficiency evaluation of the IS ISCCP and ISDCP control a development of the control efficiency criterion is necessary.

The proposed solution method. In the present work on the basis of the conducted investigations [4, 5, 13] and ITU [7] recommendations there were proposed the following constituent parts (subcriterions) of the IS-control efficiency criterion:

1. Technical subcriterions: the time of presence of the order for the IS in the network – T, the order blocking probability – P, the number of the orders which are waiting for service – L.

2. Economical subcriterion – the general value of the control device (by the corresponding control principle) – C.

3. The subcriterion taking into account the character of the incoming flow of orders for servicing – H.

4. The subcriterion which characterizes the degree of user's satisfaction of the service quality – Π.

1. Technical subcriterions

For the technical subcriterions calculation ISCCP is presented as one-channel mass servicing system (MSS), and ISDCP – as mass servicing network (MSN). Let us consider that the number of places in the server queue is not limited and the discipline FIFO (first came – first serviced) is used. The control device is able to serve simultaneously only one order. Servers have a constant time of servicing of the order of the correspondent class. The MSS (ISCCP) characteristics are calculated in the following way [1, 13].

On the basis of the calculation of the stationary probabilities of p_z conditions of MSS we'll get the way of technical subcriterions calculating for MSS (ISCCP).

The average number of orders in the queue of $\overline{L}_{ISCCP}$ is calculated as a sum of probabilities of p_z conditions, by which there is an order in the queue.

$$\overline{L}_{ISCCP} = \sum_{z} m_z p_z , \quad (1)$$

where z – is a counting number of the conditions by which there is an order in the queue, m_z – the number of orders in the queue in condition z.

The average number of orders in the system $\overline{M}_{ISCCP}$ is calculated as a sum of probabilities of conditions by which a server services an order and when there is an order in the queue. If in a certain condition there are m orders in the queue and there is an order for servicing in the server, then the probability of these conditions must be multiplied by $m+1$.

$$\overline{M}_{ISCCP} = \sum_{q} (m_q + 1) p_q , \quad (2)$$

where q – the counting number of the conditions by which a server services this order and when there is an order in the queue.

The probability of the loss of order $\overline{P_Б}$ is calculated as the sum of the probabilities of the conditions by which the queue is filled up:

$$\overline{P_Б} = \sum_{v} p_v , \quad (3)$$

where v – is the counting number of conditions by which the queue is filled up.

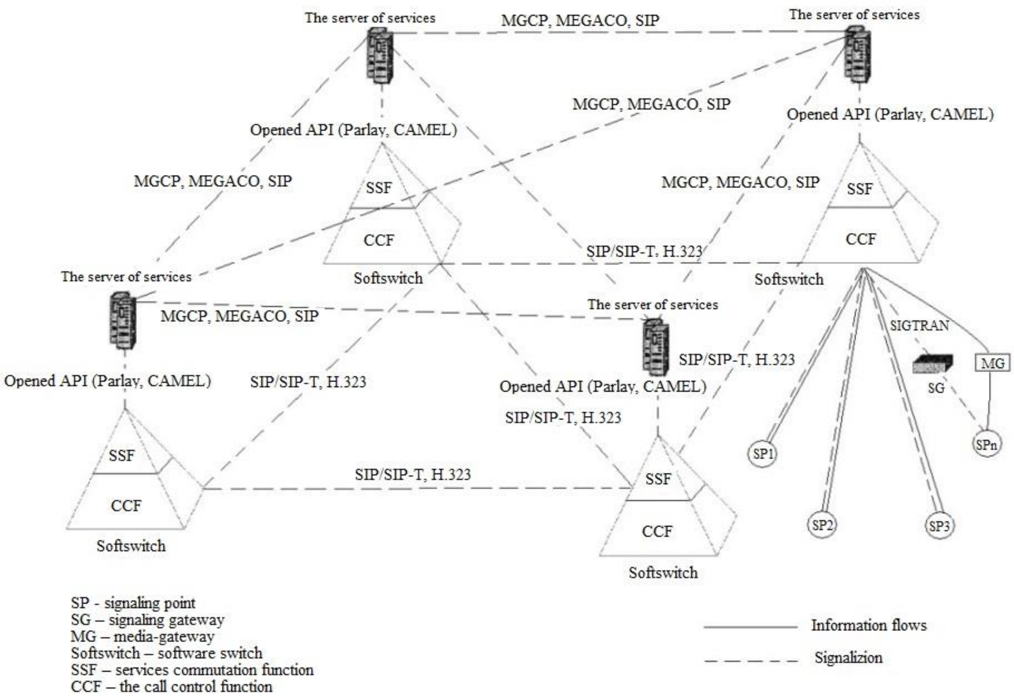

Fig. 3. The NGN architecture with ISDCP

On the basis of the calculation of the stationary probabilities of p_z conditions of MSN we'll get the way of calculation of the technical subcriterions for MSN (ISCCP).

The average number of orders in the queue the i-server $\overline{L_i}$ is calculated as the sum of the probabilities of the conditions by which in the queue of the i-server an order is present. When in the definite condition in the queue m orders are present, then the probability of this condition must be multiplied by m.

$$\overline{L_i} = \sum_{z} m_z p_z , \quad (4)$$

where z – is a counting number of the conditions by which in the queue of the i-server an order is present.

Then the general length of the queue by ISCCP:

$$\overline{L}_{\text{ISDCP}} = \sum_{i=1}^{D} \overline{L_i} , \quad (5)$$

where D – is a number of servers.

The work load of servers is defined as a sum of probabilities of the conditions by which the corresponding server is busy with orders servicing:

$$\rho_i = \sum_{l} p_l , \quad (6)$$

where l – is a counting number of conditions at which i-server is busy with servicing of the orders.

The productive capacities of the i-nodes (the serviced orders intensity) are defined by formula:

$$\lambda_i^{'} = \rho_i \mu_i . \quad (7)$$

The orders loss probability on the corresponding server is calculated as follows:

$$\overline{P_{Бi}} = 1 - \frac{\lambda_i^{'}}{\lambda_{\Sigma}} , \quad (8)$$

where λ_{Σ} – is the sum of intensities of all flows of orders which came to the i-server.

The orders loss probability in the control system:

$$\overline{P_{Бj}} = 1 - \frac{\sum_{i=1}^{D} \lambda_i^{'}}{\sum_{i=1}^{D} \lambda_i} \quad (9)$$

According to the formula introduced by Little [9] at any character of the orders flow, by any servicing time distribution and by any servicing discipline the average time of the presence of the order in the system (the queue) is equal to:

$$T_{syst} = \frac{1}{\lambda} L_{syst}, \quad (10)$$

where L_{syst} – is an average number of orders in the system, λ – the incoming orders flow intensity.

2. *Economical subcriterion.*

One of the subcriterions of the criterion of the control efficiency of IS both of ISCCP and of ISDCP in NGN is the value of IS – $\bar{C}$, to be more exact, the net present value C. The C calculation formulas for ISCCP and ISDCP would be identical in their general terms.

We'll introduce the following symbols for the calculation:

P – the IS introduction incomes volume;

B_u – an investment capital;

B_e – the recurrent expenses for IS;

T – the IS realization and exploitation period (the number of years);

t – the counting number of every year;

r – the annual reference rate.

C can be defined as a general difference between deduced incomes and deduced expenses for IS after all years of realization and exploitation:

$$C = \sum_{t=1}^{T} \frac{(P_t - B_{ut} - B_{et})}{(1+r)^{t-1}} \qquad (11)$$

3. The subcriterion taking into account the character of the orders flow coming to IS.

In the contemporary investigations [11, 12] is shown that the network traffic possesses the pronounced properties of self-similarity. Taking into account these properties allow characterizing more exactly the behavior of the network traffic than by using of exponential models. For this very reason by the IS-control efficiency evaluation a subcriterion is introduced which takes into account the self-similarity property of the orders flows coming for servicing.

The taking into consideration of the incoming flow character is realized on the basis of introducing of the Herst parameter H, $0 < H < 1$, defined for the temporal series $x(t_i)$, t_i – the discrete moments of time, $1 \le i \le N$. If $H > 0.5$, then the investigated flow possesses a long-term memory and it is self-similar [11, 12].

4. Subcriterion taking into account users' opinion.

In publications concerning IS – control efficiency evaluation [5, 13] are considered preferentially the technical characteristics in correspondence with requirements to the network quality indicators for services based on the IP [10]. However, outgoing of the up-to-date ITU-recommendations [7], by evaluation of telecommunication service it is necessary to take into account the degree of satisfaction of the users of the service quality what can be realized, for instance, by using of approaches presented in the work [4].

Consequently, the IS-control efficiency criterion – Q is presented in the vector form:

$$\bar{Q} = (T, P, L, C, H, \Pi) \qquad (12)$$

By comparing of the control devices efficiency with the different principles of control on the basis of the vector criterion in the form (12) it is necessary that all subcriterions of the control device with a definite control principle should correspond to analogic subcriterions of the control device with the another control principle. However, it is not always possible to compare the control devices with various control principles with the help of the vector the elements of which these subcriterions are. The most frequently at first the vector criterion is formed and after that there is realized a transition to the resulting scalar criterion (RSC) by 10 methods presenting the possibility of quantitative evaluation of the IS-control efficiency [9, 13].

For creation of RSC an additive utility function is used [6]:

$$Q(x) = \sum_{k=1}^{S} \mu_k Q_k(x)\,,\ \mu_k \ge 0,\ \sum_{k=1}^{S} \mu_k = 1\,, \qquad (13)$$

where Q_k is the k-subcriterion value and it is usually presented in number of points in point system accepted; μ_k – weight coefficient defining the k-subcriterion significance; S – the number of subcriterions.

For determination of the subcriterions weight coefficients values there are usually used expert estimations on which basis the priorities matrix [9] is formed. By creation of the priorities matrix the Kendall's concordation coefficient W_k, which characterizes the concordation degree of experts by assessment of marks, must satisfy the condition $W_k \ge 0.7$.

The results obtained. The main point of the proposed IS-control efficiency evaluation method consists in the following.

A certain counting number is assigned to every of subcriterions which number corresponds to their sequence. By that the sequence of subcriterions is organized corresponding to their weight coefficients which were obtained on the basis of the experts' assessments. The results of these assessments are places into the priorities matrix in the form of table 2.

In every row of the priorities matrix there is indicated for every k-subcriterion ($k = \overline{1, n}$, where k – is the number of the given subcriterion, n – is the number of subcriterions), its weight characteristics relative to other subcriterions. For example, by expert comparison of the subcriterions T and P was obtained that weight characteristics of the subcriterion T are twice as much as such characteristics of the subcriterion P; then in the string T and in the column P the index "2" is logged, and in the string P and in the column T – the index "1" is logged. Analogically the other priority matrix elements are logged. In the last column of the priority matrix 11 there is formed a sum of weight characteristics for every subcriterion. The ratio of the indicated sums gives the possibility to determine the weight coefficient μ_k for every k-subcriterion.

Let us consider an example of evaluations of these subcriterions by experts which subcriterions were brought to the priorities matrix (Table 2):

Table 2. Priorities matrix

	T	*P*	*L*	*C*	*H*	*П*	μ_k
T	0	2	5	5	5	10	27
P	1	0	1	2	5	5	14
L	1	1	0	5	5	5	17
C	1	1	1	0	5	2	10
H	1	1	1	1	0	1	5
П	1	1	1	1	1	0	5

For determination of the weight coefficients мюk we have a system of equations:

$$\frac{\mu_1}{\mu_2} = \frac{27}{14}, \frac{\mu_2}{\mu_3} = \frac{14}{17}$$

from which $\mu_1 = 0{,}35$, $\mu_2 = 0{,}18$, $\mu_3 = 0{,}22$, $\mu_4 = 0{,}13$, $\mu_5 = 0{,}06$ и $\mu_6 = 0{,}06$

So for the example considered (table 2) the additive utility function has appearance:

$$Q(x) = 0{,}35Q_1(x) + 0{,}18Q_2(x) + 0{,}22Q_3(x) + 0{,}13Q_4(x) + 0{,}06Q_5(x) + 0{,}06Q_6(x)$$

For association of subcriterions which are disjoint to each other it is necessary to bring them to the unique system of assessment in the points. In the present case let us bring all subcriterions to five points scale of assessment.

In the table 3 there is presented an example of conversion into five points scale of the values for technical subcriterions. So for bringing of the T – subcriterion value into 5-points scale it is assumed: $0 \le T < 200$ corresponds to 512 points, $200 \le T < 400$ corresponds to 4 points and so on. By the same principle a scale for other subcriterions is created.

In table 4 is presented a transition scale into 5 points scale of the values of the other subcriterions – C, H and $П$.

For the IS-control efficiency evaluation which is realized by ISCCP and ISDCP there was realized an imitational modeling. This modeling was conducted in the system NS-2. The modeled system consists of 100 subscribers generating orders for IS, every order being presented by the group of 3-8 packets and every of them has size of 100 bites. The maximal length of the queue for servicing – 2000 orders. This modeling was conducted by the Herst index value *H*=0,9. The general cost of the control device was assumed *C*=7000 conventional units [13]. In table 5 are presented the modeling results by the various incoming flow intensity and the calculation of efficiency criterions of ISCCP function of utility *Q(x).*

Table 3. Transition of the subcriterions values to 5 points scale

Assessment in points	*T* – time of presence of the order for IS in the network (ms)	*P* – order blocking probability	*L* – number of orders which are waiting for service
5	$0 \le T < 200$	$0 \le P < 0{,}02$	$0 \le L < 1100$
4	$200 \le T < 400$	$0{,}02 \le P < 0{,}03$	$1100 \le L < 1200$
3	$400 \le T < 600$	$0{,}03 \le P < 0{,}04$	$1200 \le L < 1300$
2	$600 \le T < 800$	$0{,}05 \le P < 0{,}06$	$1300 \le L < 1400$
1	$800 \le T \le 1\,000$	$0{,}06 \le P \le 0{,}07$	$1400 \le L \le 1600$

Table 4. Transition of subcriterions values into five points scale

Assessment in points	*C* – value in conventional units	*P* – character of incoming flow (Index of Herst)	*П* – quality category and user's assessment
5	$0 \le C < 6\,000$	$0 \le H < 0{,}2$	The highest (excellent)
4	$6\,000 \le C < 7\,000$	$0{,}2 \le H < 0{,}4$	High (good)
3	$7\,000 \le C < 8\,000$	$0{,}4 \le H < 0{,}6$	Average (acceptable: some part of users appreciates quality as unsatisfactory)
2	$8\,000 \le C < 9\,000$	$0{,}6 \le H < 0{,}8$	Low (bad: majority of users appreciates quality as unsatisfactory)
1	$9\,000 \le C \le 10\,000$	$0{,}8 \le H < 1$	Unacceptable (not recommended)

Table 5. Calculations results for ISCCP

λ (Mbite s/sec)	*T*		*P*		*L*		*C*	*H*	*П*	*Q*
	ms	points	units	points	units	points				
10	461,316	3	0,005944	5	970	5	3	1	5	3,8
20	469,667	3	0,011505	5	1077	5	3	1	5	3,8
30	479,486	3	0,01246	5	1180	4	3	1	4	3,52
40	518,677	3	0,02	4	1250	3	3	1	4	3,12
50	597,841	3	0,029	4	1300	2	3	1	3	2,84
60	656,752	2	0,033	3	1367	2	3	1	3	2,31
70	728,196	2	0,037	3	1398	2	3	1	2	2,25
80	813,7236	1	0,045	2	1415	1	3	1	2	1,5
90	908,26	1	0,051	1	1435	1	3	1	1	1,26
100	993,256	1	0,06	1	1555	1	3	1	1	1,26

The ISDCP efficiency criterion calculation – the additive utility function *Q(x)* – was conducted by the following initial data: *C*=1000 conventional units, *H*=0,9. The calculations results are brought into table 6.

Table 6. The calculations results for ISDCP

λ	*T*	*P*	*L*	*C*	*H*	*П*	*Q*
10	3	5	5	1	1	5	3,54
20	3	5	5	1	1	5	3,54
30	3	5	5	1	1	5	3,54
40	3	5	4	1	1	4	3,26
50	3	4	4	1	1	4	3,08
60	2	4	3	1	1	4	2,51
70	2	4	3	1	1	3	2,45
80	2	2	3	1	1	2	2,03
90	2	2	3	1	1	2	2,03
100	2	2	3	1	1	2	2,03

On the basis of the obtained results there were constructed graphs of the dependence of the additive utility functions values for ISCCP and ISDCP from the intensity of the incoming orders for IS – *λ* (Fig.4)

As it can be seen from the fig.4, by small values of the incoming intensity of the order *λ*, owing to the smaller cost of equipment and owing to small loads, ISCCP is more efficient. However by growing of *λ* the advantage of ISCCP on ISDCP becomes far less, and by *λ* > 30 1/hour the efficiency of using ISDCP is greater than of using ISCCP.

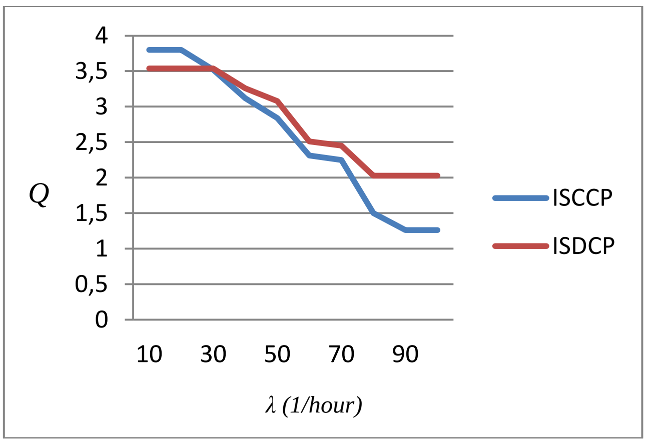

Fig.4. The graph of dependence of additive utility function from the intensity of incoming of orders for IS

The IS-control efficiency evaluation method presented in the actual work gives the opportunity of defining which of the control principles – ISCCP or ISDCP is more preferred to use by construction of IS- control system.

Conclusion. There is proposed a criterion of definition of the efficiency of the IS-control devices with different control principles. There is also given reasons for using of the following subcriterions of the proposed criterion:

● technical subcriterion;

● economical subcriterion;

● subcriterion taking into account the character of the incoming flow of orders for servicing;

● subcriterion characterizing the degree of satisfaction of the service quality.

There is proposed a method of calculation of the criterion of efficiency as an additive function of utility in which all the components are presented in the unified system of assessment of the points. Thee was conducted a calculation of criterion of ISCCP and ISDCP efficiency which calculation has shown the possibility of using of the proposed method for a definition of the sphere of preferred using of ISDCP and ISCCP in the conditions of the growing of the intensity of incoming traffic.

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Метод оценки эффективности управления интеллектуальным сервисом

Б. Л. Пустовой

Аннотация. Предложен критерий оценки эффективности управления интеллектуальным сервисом. При построении критерия во внимание взяты, помимо технических и экономических характеристик, также характер поступающего потока и степень удовлетворенности пользователей качеством сервиса. Представлен пример расчета предложенного критерия для централизованного и децентрализованного принципа управления интеллектуальным сервисом в сетях следующего поколения.

Ключевые слова: *интеллектуальный сервис; сети следующего поколения; критерий качества; качество сервиса; децентрализованный принцип; централизованный принцип.*