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Control Efficiency of Persistence of Biotronics Networks

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Introduction

When developing territorial control systems of interfaces of biological and electronic objects – biotronics systems (BTS), their networks are formed [1], problems of efficiency of information transmission over them emerge [2]. Typical solutions to these problems are analyzed in many publications, e.g., [3-5]. Nevertheless constantly improved electronic networks acquire more and more new features. Features of persistence [6], statistical efficiency dynamics and other become characteristic to them. Influence of these features on efficiency of BTS networks is still weakly explored. There is a lack of methods for evaluation of persistence influence on efficiency of these networks. Possibilities for rational persistence control are still completely uninvestigated. Persistence control decision-making mechanisms are still unclear. A method for evaluation of stochastic information transmission possibilities should be created.

For better understanding of fundamental principles of persistence control of BTS network, let's analyze further presented example.

BTS network persistence control scheme

As it was already mentioned several times, persistence

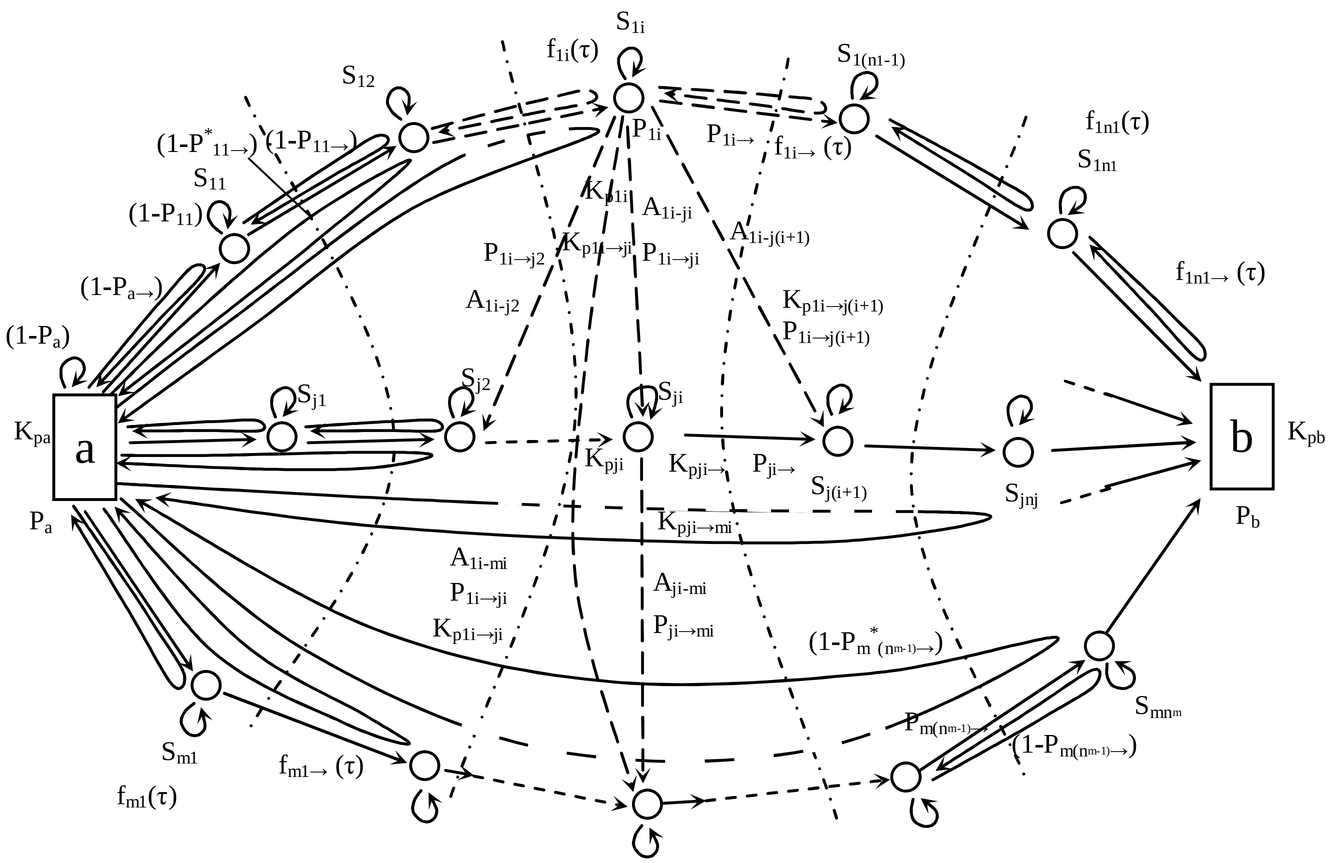

Fig. 1. Directional graph of ES network

is characteristic to many electronic systems (ES) and their networks. For most cases this is an attribute of systems. When task performance fails using one method, ES tries to continue the process or repeat it in some other way. That increases the efficiency of these systems. But often methods for evaluation of such ES potential are missing, which could be used to evaluate task accomplishment probabilities. Let's consider typical problem of information transmission from subscriber *a* to subscriber *b* using ES network. Assume that ES network shown in Fig. 1 is used for this purpose. This network consists of *m* links each having $n_1, n_2, \ldots n_m$ ES with interfaces between them.

Probability that subscriber *a* will direct information into a→S_{11} interface on the first attempt

$$P_{ua}^{(1)} = K_{pa} \cdot P_a; \tag{1}$$

here K_{pa} and P_a is preparedness coefficient of subscriber *a* and probability that it will successfully accomplish its actions by directing information into a→S_{11} interface on the first attempt. When there are no persistence measures in the network, probability that information will reach subscriber over the first link

$$P_1 = K_{pa} \cdot P_a \cdot K_{pa1\to} \cdot P_{a1\to} \cdot K_{p11} \cdot P_{11} \cdot K_{p11\to} \cdot P_{11\to} \cdot \ldots$$
$$\ldots \cdot K_{p1i} \cdot P_{1i} \cdot K_{p1i\to} \cdot P_{1i\to} \cdot \ldots \cdot K_{pb} \cdot P_b; \tag{2}$$

here $K_{pa1\to}$, $K_{p11\to}$, $K_{p1i\to}$ are preparedness coefficients of interfaces beginning at subscriber *a* and systems (nodes) S_{11} and S_{1i}; K_{p1i} are task accomplishment probabilities of i-th system and interface located after it (S_{1i}→ $S_{1(i+1)}$); K_{pb} and P_b are preparedness coefficient of subscriber *b* and task accomplishment probability.

If persistence is characteristic to subscriber *a*, then if directing of information into interface a→S_{11} fails on the first attempt, following attempts will proceed. After the first repeated attempt (second in a row)

$$P_{ua}^{(2)} = K_{pa}[1-(1-P_a)^2] \tag{3}$$

and after v_a-th in a row

$$P_{ua}^{(V)} = K_{pa}[1-(1-P_a)^{Va}]. \tag{4}$$

Then task accomplishment probability of the entire first link

$$P_1^{(1)} = K_{pa}[1-(1-P_a)^{Va}] \cdot K_{pa\to}[1-(1-P_{a\to})^{Va\to}] \cdot \ldots$$
$$\ldots \cdot K_{p1i}[1-(1-P_{1i})^{V1i}] \cdot K_{p1i\to}[1-(1-P_{1i\to})^{V1i\to}] \cdot \ldots$$
$$\ldots \cdot K_{pb}[1-(1-P_b)^{Vb}]; \tag{5}$$

here $V_{a1\to}$, V_{1i}, $V_{1i\to}$ and V_b are numbers of attempts to accomplish tasks of the first interface beginning with node *a*, system S_{1i} and interface beginning at it (S_{1i}→ $S_{1(i+1)}$) and subscriber *b*.

Probability of successful transmission of information into the system S_{12} when earlier indicated level of persistence is present

$$P_{12}^{(\to)} = K_{pa}[1-(1-P_a)^{Va}] \cdot K_{pa1\to}[1-(1-P_{a1\to})^{Va1\to}] \times$$
$$\times K_{p11}[1-(1-P_{11})^{V11}] \cdot K_{p11\to}[1-(1-P_{11\to})^{V11\to}]. \tag{6}$$

If after failing to do that (e.g., because of too long delay) there is a possibility ($1-P^*_{11\to}$) to return from subscriber *a* to try to repeat transmission from the beginning, then in this case probability that information will reach system S_{12}

$$P_{12}^{(*)} = P_{12}^{(\to)} + (1-P_{12}^{(\to)})(1-P^*_{11\to})[1-(1-P_{12}^{\to})^{V_{11\to*}-1}]; \tag{7}$$

here $V_{11\to*}$ is number of returns from access points of system S_{12} to subscriber *a*. Also task accomplishment probabilities in respect of returns from system S_{1i} can be calculated analogously:

$$P_{1i}^{(*)} = P_{1i}^{(\to)} + (1-P_{1i}^{(\to)})(1-P^*_{1(i-1)\to})[1-(1-P_{1i}^{(\to)})^{V_{(i-1)1\to*}}]; \tag{8}$$

here $V_{1(i-1)\to*}$ is number of returns from access points of system S_{1i} to subscriber *a*.

The need to return can also emerge when system S_{1i} is no longer capable of performing tasks assigned to it. Assume that probability that S_{1i} will accomplish its tasks (together with systems located in front of it and interfaces between them) when this type of persistence is available, equals $P_{1i}^{(**)}$. Then probability of successful information transmission over the first link to subscriber *b*

$$P_1^{(\cdot)} = K_{pa}[1-(1-P_a)^{Va}] \cdot P^{(*)}_{1n_{1\to}} \cdot K_{pb}[1-(1-P_b)^{Vb}]. \tag{9}$$

When subscriber *b* is also capable to request the repeat of information transmission with probability ($1-P_b^*$), then:

$$P_{1b}^{(II)} = K_{pa}\left[1-(1-P_a)^{V_a}\right] \cdot P^*_{1n_1\to} \cdot$$
$$\cdot K_{pb}\left\{\left[1-(1-P_b)^{V_b}\right] + (1-P_b)^{V_b} \cdot (1-P_b^*) \cdot \left[1-(1-P^{(*)}_{1n_1\to})^{V_{b*}}\right]\right\}; \tag{10}$$

here V_{b*} is number of returns from subscriber *b* to subscriber *a*.

Determination of persistence levels

Magnitudes $V_a, \ldots, V_{1i}, V_{1i\to}, V_{1i*}, V_{1i\to*}, \ldots V_b$ and V_{b*} can not be infinite. They depend on reserve of allowable losses (delays, number of lost packets, etc.). Assume that allowable delay of information transmission from *a* to *b* should not be higher than T_l, and its successful transmission (on the first attempt at all links) lasts for T_s, then reserve of losses is of magnitude ΔT.

$$\Delta T = T_l - T_s. \qquad (11)$$

Let's say, that actions of subscriber a during one attempt last T_a, T_{1i} for system S_{1i}, and $T_{1i\rightarrow}$ for system located after it, of subscriber b – T_b, and in case of returns to subscriber a from system S_{1i} – T_{1i*}. Then maximal numbers of repeats:

$$V_{a_{\max}} = \frac{\Delta T}{T_a}; \qquad (12)$$

$$V_{a1\rightarrow_{\max}} = \frac{\Delta T - V_a \cdot T_a}{T_{a1\rightarrow}}; \qquad (13)$$

$$V_{1i\max} = \frac{\Delta T - \left(V_a \cdot T_a + V_{a1\rightarrow} \cdot T_{a1\rightarrow} + \sum_{j=1}^{i-1} T_{1j\rightarrow} \cdot V_{1j\rightarrow} \right)}{T_{1i}} + \frac{\sum_{j=1}^{i-1} T_{1j} \cdot V_{1j} + \sum_{j=1}^{i-1} T_{1j*} \cdot V_{1j*} + \sum_{j=1}^{i-1} T_{1j\rightarrow*} \cdot V_{1j\rightarrow*}}{T_{1i}}; \qquad (14)$$

$$V_{b*\max} = \frac{\Delta T - \left(V_a T_a + V_{a1\rightarrow} \cdot T_{a1\rightarrow} + \sum_{j=1}^{n_1} T_{1j} V_{1j} + \sum_{j=1}^{n_1} T_{1j\rightarrow} \cdot V_{1j\rightarrow} \right)}{T_{b*}} + \frac{\sum_{j=1}^{n_1} T_{1j*} \cdot V_{1j*} + \sum_{j=1}^{n_1} T_{1j\rightarrow*} \cdot V_{1j\rightarrow*} + V_b \cdot T_b}{T_{b*}}; \qquad (15)$$

here T_{b*} is duration of one repeated information transmission over the first link from subscriber a to subscriber b (after it requested transmission).

$$T_{b*} = V_a \cdot T_a + V_{a1\rightarrow} \cdot T_{a1\rightarrow} + \sum_{j=1}^{n_1} T_{1j} V_{1j} + \sum_{j=1}^{n_1} T_{1j\rightarrow} \cdot V_{1j\rightarrow} + \sum_{j=1}^{n_1} T_{1j*} \cdot V_{1j*} + \sum_{j=1}^{n_1} T_{1j\rightarrow*} V_{1j\rightarrow*} + V_b \cdot T_b. \qquad (16)$$

When $V_{a\max}, \ldots, V_{1i\max}, \ldots, V_{b*\max}$ are smaller than one, there are no possibilities to repeat transmission. Average probability of successful transmission of information from subscriber a to subscriber b using network shown in Fig. 1 (without changing links)

$$P_{ab} = \sum_{j=1}^{m} A_j \cdot P_{jb}^{(II)}; \qquad (17)$$

here A_j is the priority of j-th link; $P_{jb}^{(II)}$ is the probability of successful information transmission over j-th link to subscriber b (considering persistence of the j-th link).

$$\sum_{j=1}^{m} A_j = 1. \qquad (18)$$

This calculation method does not assess possible interfaces between separate links ant stochastic nature of losses (e.g., T_{ji} and other).

Assessment of stochastic nature of persistence

Assume that only graph nodes (systems) are able to implement interfaces between links; transition to other link is made only when transmission using the earlier one becomes unpractical (or impossible); underlying link is always selected when transiting to other link and priorities of directions (nearness) is always considered. Let's analyze possible transitions from system S_{1i} to other links. If links are placed so that their priorities

$$A_1 \rangle A_2 \rangle \ldots \rangle A_j \rangle \ldots \rangle A_m, \qquad (19)$$

then the first information transmission attempt will be made using 1st link. If it becomes clear during transmission, that transmission using this link is purposeful no more (e.g., delay upon reaching system S_{1i} is too high and opportunity to use interface $S_{1i\rightarrow}$ in it is lost or it is forecasted with high probability that delays in further route will exceed remaining reserve of losses, etc.), transition is made to the second link by assessing (19). If it becomes obvious that this decision is not good, then transitions are made to others, e.g., j-th link. In most cases interfaces $S_{1i\rightarrow b}$ or $S_{1i\rightarrow}S_{jnj}$ are impossible since they would have been already used when network was created. Thus direction priorities of these interfaces:

$$A_{1i} - b = 0; \qquad (20)$$

$$A_{1i} - jn_j = 0; \qquad (21)$$

$$A_{1i} - j(n_j - 1) = 0; \qquad (22)$$

but

$$A_{1i} - j(i+1) > 0. \qquad (23)$$

Nearness zones in Fig. 1 are separated by vertical dotted lines. They could represent territorial and (or) structural nearness of links. Furthermore

$$\sum_{s=i+1}^{n_j} T_{js} \cdot V_{js} \langle \sum_{s=i}^{n_j} T_{js} \cdot V_{js}. \qquad (24)$$

Thus

$$A_{1i-j(i+1)} \rangle A_{1i-ji} \rangle A_{1i-j(i-1)}. \qquad (25)$$

It is considered, that preparedness coefficients of these interfaces

$$K_{p1i\to j(i+1)} \approx K_{p1i\to ji} \approx K_{p1i\to j(i-1)} \cdots \quad (26)$$

and their task accomplishment probabilities

$$P_{1i\to j(i+1)} \approx P_{1i\to ji} \approx P_{1i\to j(i-1)} \cdots \quad (27)$$

If it becomes clear that

$$K_{p1i\to j(i+1)} \langle\langle K_{p1i\to ji}, \quad (28)$$

$$P_{1i\to j(i+1)} \langle\langle P_{1i\to ji} \quad (29)$$

then problem would be more difficult and it would be necessary to search for most rational variant of transition to j-th link.

It should be noted that unequality (19) can be different in each nearness zone. It can be conditioned by not equal losses of reserve in separate different systems of links or their interfaces located in t-th nearness zone. But nearness priorities of interfaces S_{1i} with j-th link always satisfy condition (25).

Forecasting of reserve losses

Random character of reserve losses in systems and interfaces between them determines the fact that their overall value (e.g. total delay)

$$T_{1i\to 1n_1\to} = F\begin{bmatrix} f_{1i\to}(T_{1i\to}), f_{1(i+1)}(T_{1(i+1)}), f_{1(i+1)\to}(T_{1(i+1)\to}), \ldots \\ \ldots f_{1n_1\to}(T_{1n_1\to}) \end{bmatrix}, \quad (30)$$

here $f_{1i\to}(T_{1i\to})$ is distribution density of values of losses $(T_{1i\to})$ in interface $S_{1i} \to S_{1(i+1)}$. When values of losses in systems and interfaces between them are additive independent random quantities, then distribution density of total losses values of two adjacent network components

$$f_{1i\to 1(i+1)}(T_{1i\to 1(i+1)}) = \int_0^\infty f_{1i\to}(T_{1i\to}) \cdot f_{1(i+1)}(Z - T_{1i\to}) dT_{1i\to}; \quad (31)$$

here

$$Z = T_{1i\to} + T_{1(i+1)}. \quad (32)$$

When

$$f_{1i\to}(T_{1i\to}) \approx f_{1(i+1)}(T_{1(i+1)}) = \\ = \begin{cases} 0, \text{ when } T_{1i\to} \langle 0 \text{ and } T_{1(i+1)} < 0; \\ \lambda e^{-\lambda T_{1i\to}}, \text{ when } T_{1i\to} \rangle 0 \text{ and } T_{1(i+1)} > 0. \end{cases} \quad (33)$$

Then

$$f_{1i\to 1(i+1)}(Z) = \lambda^2 z e^{-\lambda z}, \; if \; z \ge 0; \quad (34)$$

here λ is parameter of distribution of values of reserve losses. When condition (33) is valid, density of distribution of reserve losses values of remaining link part from S_{1i} to b

$$f_{1i-b}(Z_1) = \frac{\lambda(\lambda Z_1)^{\gamma-1}}{(\gamma-1)!} e^{-\lambda Z_1}; \quad (35)$$

$$Z_1 = T_{1i\to} + T_{1(i+1)} + \ldots + T_{1n_1}; \quad (36)$$

$$\gamma = 2(n_1 - i) + 1. \quad (37)$$

Graph of distribution density described by formula (35) is shown in Fig. 2.

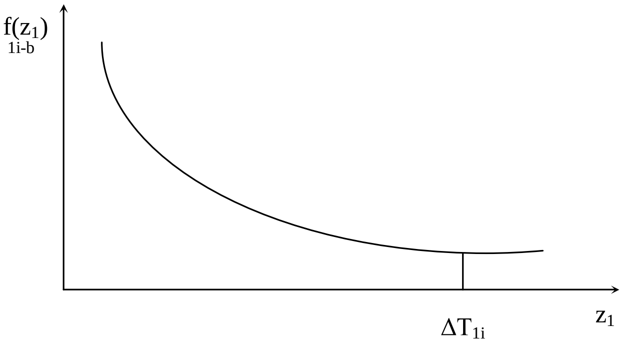

Fig. 2. Forecasting of reserve losses values

When the value of total reserve losses up to S_{1i} (inclusively) amounts $T_{\sum 1i}$ then probability that their real value (T_{1i}) in all 1st link will not exceed T_e is calculated in following way:

$$P_1(T_{1f} \le T_e) = \int_0^{\Delta T1i} t_{1i-b}(z_1) dz_1; \quad (38)$$

here

$$\Delta T_{1i} = T_e - T_{\sum 1i}. \quad (39)$$

Persistence control

By selecting level of guarantees ($P_1(T_{1f} \le T_e)$) (e.g., $P_g(T_{1f} \le T_e) \ge 0{,}9$), conditions can be obtained under which 1st link (from S_{1i}) is reselected into another (e.g., 2nd or i-th).

If

$$P_1(T_{1f} \le T_e) < P_g(T_{1f} \le T_e), \quad (40)$$

then analogous conditions are verified

$$P_2^{(I)}(T_{(1+2)f} \le T_e) = \int_0^{\Delta T_{1i}} f_{2(i+1)-b}(z_2) dz_2 \ge P_g(T_{(1+2)f} \le T_e); \quad (41)$$

$$P_2^{(II)}(T_{(1+2)f} \le T_e) = \int_0^{\Delta T_{1i}} f_{2i-b}(z_3) dz_3 \ge P_g(T_{(1+2)f} \le T_e); \quad (42)$$

$$P_2^{(III)}(T_{(1+2)f} \le T_e) = \int_0^{\Delta T_{1i}} f_{2(i-1)-b}(z_4)dz_4 \ge P_g(T_{(1+2)f} \le T_e); \quad (43)$$

$$P_{ji}(T_{(1+j)f} \le T_e) = \int_0^{\Delta T_{1i}} f_{j(i+1)-b}(z_k)dz_k \ge P_g(T_{(1+j)f} \le T_e); \quad (44)$$

here $P_2^{(I)}(\cdot)$, $P_2^{(II)}(\cdot)$ and $P_2^{(III)}(\cdot)$ are probabilities, that total values of reserve losses in second link from $S_{2(i+1)}$ to subscriber b, from S_{2i} to b and from $S_{2(i-1)}$ to b will not exceed ΔT_{1i}; $P_{ji}(T_{(1+j)f} \le T_e)$ is the probability that total value of indicated losses in j-th link from $S_{2(i+1)}$ to b will not exceed ΔT_{1i}; $f_{2(i+1)-b}(z_2)$, $f_{2i-b}(z_3)$ and $f_{2(i-1)-b}(z_4)$ are analogous $f(z_1)$ in secong link part from $S_{2(i+1)}$, S_{2i} and $S_{2(i-1)}$ to b; z_2, z_3 and z_4 are analogous to z_1; $f_{j(i+1)-b}(z_k)$ is analogous to $f_{1i-b}(z_1)$ only calculated for part of j-th link from $S_{j(i+1)}$ to b.

If $P_2^{(I)}(\cdot)$, $P_2^{(II)}(\cdot)$ and $P_2^{(III)}(\cdot)$ others satisfy (41)-(43) and other conditions, information is first attempted to transmit to $S_{2(i+1)}$. When there is no such opportunity ($K_{P_{1i\to 2(i+1)}} = 0$, or $P_{1i-2(i+1)} = 0$), it is attempted to transmit to S_{2i}, ant later to $S_{2(i-1)}$ (considering priorities of direction) and etc., until the condition is not satisfied that

$$P_2^{(x)}(T_{(1+2)f} \le T_e) \ge P_g(T_{(1+2)f} \le T_e); \quad (45)$$

here $P_2^{(x)}(\cdot)$ is task accomplishment parameter of 2nd link node, which does not guarantee with probability $P_g(T_{(1+2)f} \le T_e)$.

When highest-priority node of the second link ($S_{2(i+1)}$) is selected, task accomplishment probability

$$P_{1+2} = P_{\uparrow i} \cdot K_{P_{1i\to 2(i+1)}} \cdot P_{1i\to 2(i+1)} \cdot P_{2(i+1)-b}; \quad (46)$$

here $P_{\uparrow i}$ is task accomplishment probability in link from subscriber to S_{1i} inclusively; $P_{2(i+1)-b}$ is task accomplishment possibility in link from $S_{2(i+1)}$ to subscriber b. If after one or several stages it becomes obvious that conditions (41)-(43) are no longer satisfied, then at first information transmission attempt is made to the first link (e.g., $S_{2(i+1)}$), because its priority is the highest.

When (41)-(43) and other conditions are no longer satisfied, it is attempted to transmit information to the third link, then – to the fourth and later to j-th and finally to m-th.

When task is continued using 2nd link and when situation satisfying condition (40) is formed, information from this link can be attempted to transmit to the 3rd link, etc.

If there are no links satisfying (41)-(43) and other analogous conditions, time reserve permits repeating information transmission from the beginning (from subscriber a), and $T_{\sum 1i}$ is such that the following condition is valid:

$$\int_0^{\infty} z_B f_{1a-1i}(z_B)dz_B << T_{\sum 1i} \quad (47)$$

(here $f_{1a-1i}(z_B)$ is distribution density of total reserve input (z_B) in 1st link from subscriber a to S_{1i}), then we return to the beginning of network and attempt is made to use the fist link again. It should be noted that value of the left side of formula (47) constantly varies. Therefore it falls to renew statistical data used to recalculate it.

Conclusions

It is obvious (see formulas (3)-(8)), that efficiency of ES network, for which persistence and rational control is characteristic, is considerably higher than of the network without these features. In order to control persistence of the network it is necessary to collect statistical data about operation of separate components.

By considering statistical information about operation of BTS network components it is possible to forecast allowable losses of its reserve and to use these forecasts in persistence control.

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P. Balaišis, E. Keras, A. Valinevičius. Control Efficiency of Persistence of Biotronics Networks // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 7(87). – P. 31–36.

It is indicated, that when expanding over territories the systems of control of interfaces of biological and electronic objects – biotronics systems, their networks are created and problems of efficiency assurance of information transmission using these networks emerge. It is stated that improvement of network persistence is one of the measures for increasing this efficiency. Persistence control scheme of network of biotronics systems is presented and formulas are offered for calculation of probability of information transmission task accomplishment. Method of determination of network persistence level is presented. Stochastic nature of persistence of biotronics systems networks is emphasized. Method for forecasting of network redundancy losses is offered. Persistence control possibilities of the network of systems are investigated. Ill. 2, bibl. 6 (in English; summaries in English, Russian and Lithuanian).

П. Балайшис, Е. Кярас, А. Валиневичус. Эффективность управления упорностью сетей систем биотроники // Электроника и электротехника. – Каунас: Технология, 2008. – № 7(87). – С. 31–36.

Указывается, что при развитии на территориях систем управления взаимосвязями биологических электронных объектов – систем биотроники создаются их сети и возникают проблемы эффективной передачи информации по ним. Утверждается, что одним из способов повышения этой эффективности является повышение упорности сети. Приводится схема управления упорностью сети систем биотроники. Предлагаются формулы для расчета вероятности выполнения задачи передачи информации по этой сети. Приведен способ определения степени упорности сети систем биотроники. Предлагается метод прогнозирования потери резервов этой сети. Исследуются возможности управления упорностью сети систем биотроники. Ил. 2, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

P. Balaišis, E. Keras, A. Valinevičius. Biotronikos sistemų tinklo atkaklumo valdymo efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 7(87). – P. 31–36.

Plėtojant teritorijose biologinių ir elektroninių objektų sąsajų valdymo sistemas – biotronikos sistemas, kuriami jų tinklai, bet sunku užtikrinti informacijos perdavimo jais efektyvumą. Įrodoma, kad viena iš šio efektyvumo didinimo priemonių – didinti tinklo atkaklumą. Pateikiama biotronikos sistemų tinklo atkaklumo valdymo schema ir siūlomos formulės informacijos perdavimo užduoties įvykdymo tikimybei apskaičiuoti. Pateiktas tinklo atkaklumo laipsnio nustatymo būdas. Akcentuojamas tikimybinis biotronikos sistemų tinklo atkaklumo pobūdis. Siūlomas tinklo rezervų praradimų prognozavimo metodas. Tiriamos sistemų tinklo atkaklumo valdymo galimybės. Il. 2, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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