Control Efficiency of Persistence of Bionics Networks

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Introduction

When developing territorial control systems of interfaces of biological and electronic objects - bionics 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

![Diagram](image)

Fig. 1. Directional graph of ES network

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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, n2, ... n, ES with interfaces between them.

Probability that subscriber a will direct information into a → S11 interface on the first attempt

\[ P_{ua}^{(1)} = K_{pa} \cdot P_a \]  

(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 → S11 interface on the first attempt. When there are no persistence measures in the network, probability that information will reach subscriber over the first link

\[ P_1 = K_{pa} \cdot P_a \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdots \]

\[ \cdots \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdots \]

(2)

here \( K_{pa} \), \( P_{a \rightarrow p} \), \( P_{p \rightarrow a} \), are preparedness coefficients of interfaces beginning at subscriber a and systems (nodes) \( S_{11} \) and \( S_{12} \); \( K_{p} \) are task accomplishment probabilities of i-th system and interface located after it \( (S_{11} \rightarrow S_{12(i+1)}) \); \( K_{pa} \) and \( P_a \) 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 → S11 fails on the first attempt, following attempts will proceed. After the first repeated attempt (second in a row)

\[ P_{ua}^{(2)} = K_{pa} \cdot P_a \cdot P_a \]  

(3)

and after \( v_a \)-th in a row

\[ P_{ua}^{(v)} = K_{pa} \cdot P_a \cdot P_a \]  

(4)

Then task accomplishment probability of the entire first link

\[ P_1 = K_{pa} \cdot P_a \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdots \]

\[ \cdots \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdots \]

(5)

here \( V_{p \rightarrow a} \), \( V_{a \rightarrow p} \), \( V_{a \rightarrow p} \), and \( V_{p \rightarrow a} \) are numbers of attempts to accomplish tasks of the first interface beginning with node a, system \( S_{11} \) and interface beginning at it \( (S_{11} \rightarrow S_{12(i+1)}) \) and subscriber b.

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

\[ P_{1 \rightarrow 2} = K_{pa} \cdot P_a \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdots \]

\[ \cdots \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdots \]

(6)

If after failing to do that (e.g., because of too long delay) there is a possibility \( (1 - P_{1 \rightarrow 2} \) ) to return from subscriber a to try to repeat transmission from the beginning, then in this case probability that information will reach system \( S_{12} \)

\[ P_{1 \rightarrow 2}^{(0)} = P_{1 \rightarrow 2} \cdot (1 - P_{1 \rightarrow 2}) \]

(7)

here \( V_{1 \rightarrow 2} \) is number of returns from access points of system \( S_{12} \) to subscriber a. Also task accomplishment probabilities in respect of returns from system \( S_{11} \) can be calculated analogously:

\[ P_{v \rightarrow y}^{(0)} = P_{v \rightarrow y} \cdot (1 - P_{v \rightarrow y}) \]

(8)

here \( V_{v \rightarrow y} \) is number of returns from access points of system \( S_{11} \) to subscriber a.

The need to return can also emerge when system \( S_{11} \) is no longer capable of performing tasks assigned to it. Assume that probability that \( S_{11} \) will accomplish its tasks (together with systems located in front of it and interfaces between them) when this type of persistence is available, equals \( P_{v \rightarrow y}^{**} \). Then probability of successful information transmission over the first link to subscriber b

\[ P_1 = K_{pa} \cdot P_a \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdots \]

(9)

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

\[ P_{1 \rightarrow b}^{(0)} = K_{pa} \cdot P_a \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdot P_{p \rightarrow a} \cdot P_{a \rightarrow p} \cdot P_{p \rightarrow a} \cdots \]

(10)

here \( V_{a \rightarrow b} \) is number of returns from subscriber a to subscriber b.

**Determination of persistence levels**

Magnitudes \( V_{a \rightarrow b} \), \( V_{b \rightarrow y} \), \( V_{a \rightarrow b} \), \( V_{b \rightarrow y} \), \( V_{a \rightarrow b} \), and \( V_{b \rightarrow y} \) can not be infinite. They depend on reserve of allowable losses (delays, number of lost packets, etc.). Assume that allowable decay of information transmission from a to b should not be higher than \( T_n \) and its successful transmission (on the first attempt at all links) lasts for \( T_n \), then reserve of losses is of magnitude \( AT_n \).
\[ \Delta T = T_i - T_s. \]  

(11)

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

\[ V_{a_{\text{max}}} = \frac{\Delta T}{T_a}; \]  

(12)

\[ V_{a\rightarrow_{\text{max}}} = \frac{\Delta T - V_a \cdot T_a}{T_{a\rightarrow}}; \]  

(13)

\[
\Delta T \left( V_a \cdot T_a + V_d \cdot T_{d\rightarrow} + \sum_{j=1}^{i-1} T_j \cdot V_{j\rightarrow} \right) \\
V_{i_{\text{max}}} = \frac{\Delta T}{T_v} + \frac{\sum_{j=1}^{i-1} T_j \cdot V_j + \sum_{j=1}^{i-1} T_{j\rightarrow} \cdot V_{j\rightarrow}}{T_{i\rightarrow}}; \\
+ \frac{n \cdot T_{j\rightarrow} \cdot V_{j\rightarrow} + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{i\rightarrow}}; \\
+ \frac{n \cdot T_{j\rightarrow} \cdot V_{j\rightarrow} + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{i\rightarrow}}; \\
+ \frac{n \cdot T_{j\rightarrow} \cdot V_{j\rightarrow} + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{i\rightarrow}}; \\
\]

(14)

\[
\Delta T \left( V_{d\rightarrow} + V_{d\rightarrow} \cdot T_{d\rightarrow} + \sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} \right) \\
V_{n_{\text{max}}} = \frac{\Delta T}{T_v} + \frac{\sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{n\rightarrow}}; \\
+ \frac{\sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{n\rightarrow}}; \\
+ \frac{\sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{n\rightarrow}}; \\
+ \frac{\sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b}{T_{n\rightarrow}}; \\
\]

(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).

\[
T_{i\rightarrow} = V_a \cdot T_a + V_{d\rightarrow} \cdot T_{d\rightarrow} + \sum_{j=1}^{n} T_j \cdot V_j + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + \\
+ \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + \sum_{j=1}^{n} T_{j\rightarrow} \cdot V_{j\rightarrow} + V_b \cdot T_b. \\
\]

(16)

When \(V_{a_{\text{max}}}, \ldots, V_{i_{\text{max}}}, \ldots, V_{b_{\text{max}}}\) 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)

\[ P_{ab} = \sum_{j=1}^{m} A_j \cdot P_{j\rightarrow{ij}}. \]  

(17)

\[ \sum_{j=1}^{m} A_j = 1. \]  

(18)

This calculation method does not assess possible interfaces between separate links and stochastic nature of losses (e.g., \(T_b\) 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 impractical (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 \(S_{ij}\) to other links. If links are placed so that their priorities

\[ A_1 \cdot A_2 \cdot \ldots \cdot A_j \ldots A_m, \]

then the first information transmission attempt will be made using \(1^{\text{st}}\) link. If it becomes clear during transmission, that transmission using this link is purposeful no more (e.g., delay upon reaching system \(S_{ij}\) is too high and opportunity to use interface \(S_{ij\rightarrow}\) 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 \(S_{ij\rightarrow b}\) or \(S_{ij\rightarrow S_{j\rightarrow}}\) are impossible since they would have been already used when network was created. Thus direction priorities of these interfaces:

\[ A_{ij} - b = 0; \]  

(20)

\[ A_{ii} - jn_j = 0; \]  

(21)

\[ A_{ii} - i(n_j - 1) = 0; \]  

(22)

\[ A_{ii} - j(t + 1) > 0. \]  

(23)

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

\[ \sum_{s=1}^{n} T_{js} \cdot V_{js} \left( \sum_{s=1}^{n} T_{js} \cdot V_{js} \right)^{-1} \]  

(24)

Thus

\[ A_{ii-j(i+1)} A_{i-j \mu} A_{i-j \mu-j-1}. \]  

(25)
It is considered, that preparedness coefficients of these interfaces

\[ K_{p_{l\rightarrow j}(i+1)} \approx K_{p_{l\rightarrow j(i)}} \approx K_{p_{l\rightarrow j}(i-1)} \cdots \]  

(26)

and their task accomplishment probabilities

\[ P_{l\rightarrow j(i+1)} \approx P_{l\rightarrow j(i)} \approx P_{l\rightarrow j(i-1)} \cdots \]  

(27)

If it becomes clear that

\[ K_{p_{l\rightarrow j}(i+1)}(K_{p_{l\rightarrow j(i)}}) \]  

(28)

\[ P_{l\rightarrow j(i+1)}(P_{l\rightarrow j(i)}) \]  

(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 inequality (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_{l(i)} 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)

\[ T_{l(i)\rightarrow b(i)} = F \left[ f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) \cdots \right] \]  

(30)

here \( f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) \) is distribution density of values of losses (\( T_{l(i)\rightarrow b(i)} \)) in interface \( S_{l(i)} \rightarrow S_{b(i)} \). 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

\[ f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) = \int_0^{\infty} f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) f_{l(i)\rightarrow b(i)}(Z - T_{l(i)\rightarrow b(i)}) dT_{l(i)\rightarrow b(i)} \]  

(31)

here

\[ Z = T_{l(i)\rightarrow b(i)} + T_{l(i+1)} \].  

(32)

When

\[ f_{l(i)\rightarrow b(i)}(T_{l(i)\rightarrow b(i)}) \]  

\[ = \begin{cases} \alpha, & \text{when } T_{l(i)\rightarrow b(i)} < 0; \\ \lambda e^{-\lambda z}, & \text{when } T_{l(i)\rightarrow b(i)} \geq 0. \end{cases} \]  

(33)

Then

\[ f_{l(i)\rightarrow b(i)}(Z) = \lambda \lambda e^{-\lambda z}, \text{ if } z \geq 0; \]  

(34)

here \( \lambda \) 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 \( S_{l(i)} \) to \( b \)

\[ f_{l(i)\rightarrow b(i)}(Z) = \lambda (\lambda Z)^{\gamma - 1} e^{-\lambda Z}; \]  

(35)

\[ Z_{l(i)} = T_{l(i)\rightarrow b(i)} + T_{l(i+1)} + \cdots + T_{l(n_i)} \];  

(36)

\[ \gamma = 2(n_i - i) + 1. \]  

(37)

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

![Graph of distribution density](image)

**Fig. 2. Forecasting of reserve losses values**

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

\[ P_1(T_{l(i)} \leq T_e) = \int_0^{\Delta T_{l(i)}} f_{l(i)\rightarrow b(i)}(Z_i) dZ_i; \]  

(38)

here

\[ \Delta T_{l(i)} = T_e - T_{l(i)} \].  

(39)

**Persistence control**

By selecting level of guarantees \( (P_1(T_{l(i)} \leq T_e)) \) (e.g., \( P_1(T_{l(i)} \leq T_e) \geq 0.9 \)), conditions can be obtained under which 1st link (from \( S_{1(i)} \)) is reslected into another (e.g., 2nd or i-th).

If

\[ P_1(T_{l(i)} \leq T_e) < P_g (T_{l(i)} \leq T_e), \]  

(40)

then analogous conditions are verified

\[ P_2(T_{l(i+2)} \leq T_e) = \int_0^{\Delta T_{l(i+2)}} f_{l(i+2)\rightarrow b(i+2)}(Z_i) dZ_i \geq P_g (T_{l(i+2)} \leq T_e); \]  

(41)

\[ P_2(T_{l(i+2)} \leq T_e) = \int_0^{\Delta T_{l(i+2)}} f_{l(i+2)\rightarrow b(i+2)}(Z_i) dZ_i \geq P_g (T_{l(i+2)} \leq T_e); \]  

(42)
\[ P_l^{(i)}(T_{(i+2)f} \leq T_e) = \frac{\Delta T_i}{T_e} \int_{0}^{T_e} f(z_i)dz_i \geq P_g(T_{(i+2)f} \leq T_e); \quad (43) \]

\[ P_g(T_{t_0+jf} \leq T_e) = \frac{\Delta T_i}{T_e} \int_{0}^{T_e} f(z_i)dz_i \geq P_g(T_{t_0+jf} \leq T_e); \quad (44) \]

here \( P_l^{(i)}(\cdot), P_l^{(ii)}(\cdot) \) and \( P_l^{(iii)}(\cdot) \) are probabilities, that total values of reserve losses in second link from \( S_{2(t+1)} \) to subscriber b, from \( S_2 \) to b and from \( S_{2(t-1)} \) to b will not exceed \( \Delta T_i \); \( P_g(T_{t_0+jf} \leq T_e) \) is the probability that total value of indicated losses in j-th link from \( S_{2(t+1)} \) to b will not exceed \( \Delta T_i \); \( f_{2(i+1)-b}(z_2) \) \( f_{2(i-1)-a}(z_3) \) and \( f_{2(i-1)-b}(z_4) \) are analogous \( f(z) \) in second link part from \( S_{2(t+1)} \), \( S_2 \) and \( S_{2(t-1)} \) to b; \( z_2, z_3 \) and \( z_4 \) are analogous to \( z \); \( f_{j(i+1)-b}(z_k) \) is analogous to \( f_{j(i)-a}(z) \) only calculated for part of j-th link from \( S_{j(i+1)} \) to b.

If \( P_l^{(i)}(\cdot), P_l^{(ii)}(\cdot) \) and \( P_l^{(iii)}(\cdot) \) others satisfy (41)-(43) and other conditions, information is first attempted to transmit to \( S_{2(t+1)} \). When there is no such opportunity \( (K_{f2(t+2)} = 0, \text{ or } P_{1(t-2)}(\cdot) = 0) \), it is attempted to transmit to \( S_2 \), ant later to \( S_{2(t-1)} \) (considering priorities of direction) and etc., until the condition is not satisfied that

\[ P_l^{(x)}(T_{(i+2)f} \leq T_e) \geq P_g(T_{(i+2)f} \leq T_e); \quad (45) \]

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

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

\[ P_{i+2} = P_{t_0} \cdot K_{f2(t+1)-i} \cdot P_{i-2(t+1)} \cdot P_{(i-2)+b}; \quad (46) \]

here \( P_{t_0} \) is task accomplishment probability in link from subscriber to \( S_{t_0} \) inclusively; \( P_{(i-2)+b} \) is task accomplishment possibility in link from \( S_{2(t-1)} \) 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 \( (e.g., S_{2(t+1)}) \), 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 \( T_{\sum_l} \) is such that the following condition is valid:

\[ \int_{0}^{\infty} z_g f_{1a-l} Y(z_g)dz_g < T_{\sum_l} \quad (47) \]

(here \( f_{1a-l}(z_g) \) is distribution density of total reserve input \( (z_g) \) in 1st link from subscriber a to \( S_{t_0} \), 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.

References


It is indicated, that when expanding over territories the systems of control of interfaces of biological and electronic objects – bionics 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 bionics 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 bionics 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).


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.).
