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METHOD OF IDENTIFICATION OF DATA ROUTES IN WIRELESS SELF-ORGANIZED NETWORKS

Proposes a method for identifying data routes in wireless self-organized networks on the basis of genetic algorithms. The features of building networks of this class are described. The main tasks of the functioning of control systems of wireless self-organized networks were defined. It was emphasized that for complete functioning of wireless self-organized networks control systems was maintaining of adequate quality of their service, which included the process of changing data transmission routes and predicting the time of changes in routes. It was justified that forecasting allowed you to set up the network in time to prevent overloads, errors, failure,to predict changes in data transmission routes in different situations. The forecasting process was described. It was found out that to solve the forecasting tasks, it is advisable to use a genetic algorithm, in particular, the problems of multicritical optimization. This is due to the principle of multicritial optimization, which consists in searching for the optimal solution that simultaneously satisfies more than one target function. The routing system, its tasks and features of construction are described. The model of the forecasting subsystem is described, its importance is emphasized. The concept of identification and its methods (active, passive) are defined. It was considered the work of the rapid genetic algorithm in which due to the presence of a special elite population we can significantly reduce the time of searching for acceptable solutions on separate steps of measurements, compared to the classic genetic algorithm. The stages of the work of the rapid genetic algorithm are described and the corresponding calculations with graphical display are carried out. The essence of the proposed method is in using of a rapid genetic algorithm, which provides an acceptable quality of identification of unknown parameters of the wireless self-organized networks forecasting subsystem. On the other hand, due to the presence of a special elite population, it is possible to significantly reduce the time of searching for an acceptable solution during the processing of each measurement, turning on the classic genetic procedure of the loss optimization function only when its value exceeds some permissible threshold level. This algorithm will remain in operation even in case of non-functioning of the wireless self-organized networks forecasting subsystem.

Keywords: route identification, data transmission, mobile radio network, genetic algorithm, reinforced training.

Problem statement. At the present stage of development of modern civil and telecommunication networks, one of the most promising areas which is rapidly developing are wireless self-organized networks (WSN). These networks are popular due to their characteristics: mobility, self-organization, dynamic topology, absence of fixed data transmission routes and they are responsible for the modeling, transmission and processing of radio signals [1], [2].

The peculiarities of construction networks of this class include: the presence of inaccuracy, incompleteness and unpredictability of data obtaining; using nodes at the same time as routers, switchboards, and terminal devices; resource limitation of mobile nodes; the necessity to predict data transmission routes, the difficulty in ensuring information security, etc. On this basis, one of the main tasks during the functioning of WSN control systems is to ensure reliable data transmission with a given quality of service, uninterrupted network operation and quick recovery in case of damage, which is provided by forecasting the time of change of data transmission routes. This is due to the fact that each type of traffic that circulates in the network requires the determination of security, reliability, performance, capacity parameters, as well as the determination of requirements regarding the quality of forecasting of overload time and maintenance of BSM control systems [3], [4]. The main tasks for the full-fledged functioning of BSM control systems are to maintain sufficient quality of their service, which include the process of changing data transmission routes and predicting the time of route changes.

Analysis of recent research and publications. One of the rather important processes that directly characterize the effectiveness of the *WSN* control system is forecasting. Forecasting allows you to set up the network in time to prevent overloads, errors, failure, to predict changes in data transmission routes in different situations, which is quite important and relevant [5].

Different models and methods are used during forecasting. Among the well-known approaches are the following:

– systemic, which involves the study of quantitative and qualitative patterns of probasic processes in the system;

– historical, which consists in comprehending of each phenomenon in connection with its historical types;

– complex, which exists in a complex of phenomena in their interdependence in the context of various knowledge describing these phenomena and others;

– structural, which allows to comprehend the structure of the phenomenon that is being investigated;

– systemic-structural, which provides the study of the system as a whole, which is developing in dynamics, dismembering the system into component structural elements and the issues of their interaction. By the methods of forecasting we mean a set of thinking methods, methods that allow, on the basis of analysis of information about the forecasting of the object's components, to make a decision about future changes in the object.

Forecasting is a rather complex process that contains a fairly large number of unknown parameters and values. So, to solve the certain forecasting tasks, it is advisable to use genetic algorithms (GA), in particular, the problems of multicritical optimization. The principle of multicritial optimization is to find the optimal solution that simultaneously satisfies more than one target function. Genetic algorithms, unlike usual algorithms, do not work directly with numbers, but use for their work some subset of encoded solutions [6].

On the basis of the above, the purpose of the article is to increase the efficiency of the functioning of the WSN management system through the use of genetic algorithms while predicting changes in data transmission routes.

The aim of this paper is development of a method for identifying data transmission routes in wireless self-organized networks. This method is necessary to identify many parameters of data transmission routes (packets, segments) and increase the completeness of the identification of route parameters (total transmission delay, network routes, minimum bandwidth, reliability, downloads) in real time due to the elite population in rapid GA, under the conditions of functioning of WSN.

The main material research [5] - [17]. The routing system is a necessary component for the uninterrupted work of WSN. In it takes place the process of determining one or more routes for WSN, which are optimal within the selected criteria, between several nodes or their set. Its task is to find the optimal values of the selected indicators of service quality, as well as to ensure a balanced network load and channel resources. The peculiarities of building networks of this class include: the presence of inaccuracy, incompleteness and unpredictability of obtaining data; using nodes as routers, switches and ending devices; resource limitation of mobile nodes; difficulty in ensuring information security, etc. As a result, one of the main tasks during the operation of WSN is to ensure reliable data transmission with a given quality of service and maintain an adequate level of information security of the network [5]. Fig. 1 shows the model of the forecasting subsystem WSN.

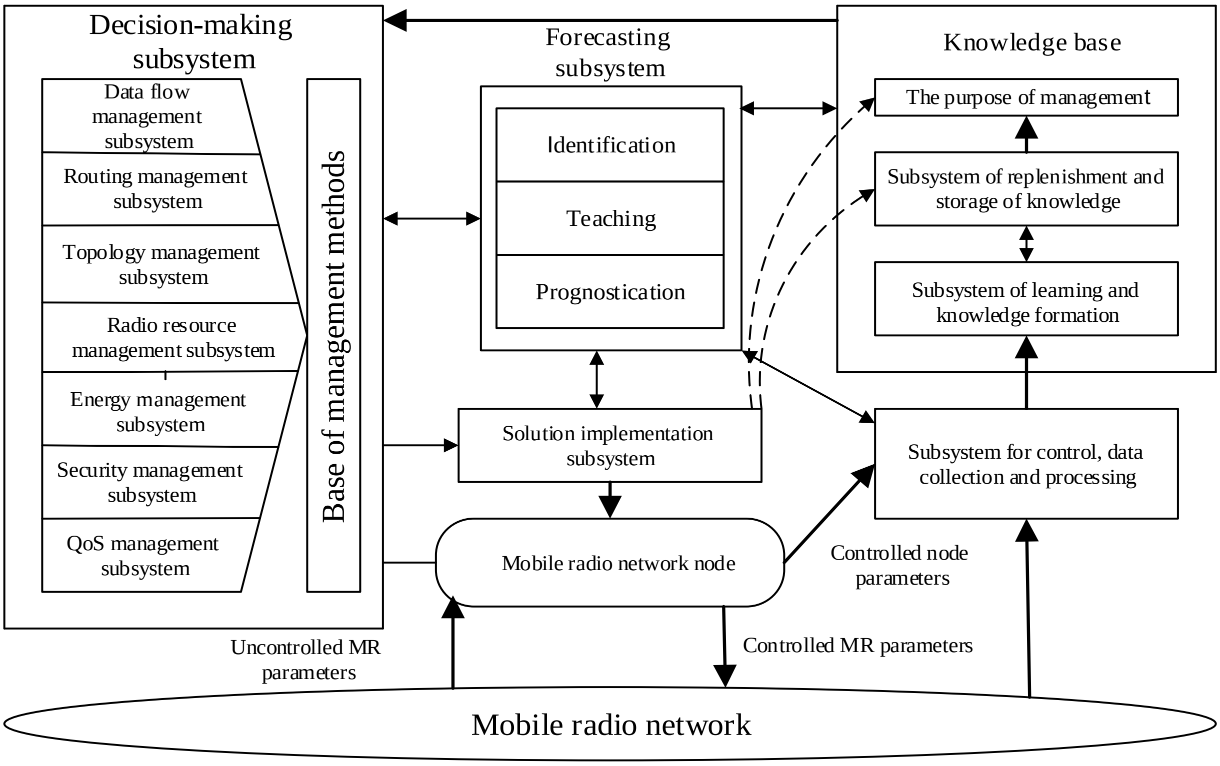


Figure 1 – Model of WSN forecasting subsystem

The forecasting subsystem collects, processes, saves the information, initial data necessary for forecasting, optimization of the output data composition, methods of measurement and provision of information, specification and final formation of the structure and the composition of the characteristics of the forecasting object, solves the problems of identification, training and forecasting in accordance with the tasks being performed by the network. This subsystem is important because it directly cooperates and influences the processes that occur in such other subsystems of the model: for the formation and implementation of solutions, the operation of the knowledge base, control, collection and processing of data. It is the main element of the model. For the development of the method for identifying data transmission routes in wireless self-organized networks, it is advisable to consider the identification unit of the WSN forecasting subsystem.

Necessary: to develop a method for identifying data transmission routes in wireless self-organized networks based on genetic algorithms, which is based on the use of a rapid genetic algorithm and is able to provide an acceptable quality of identification of data parameters of the WSN forecasting subsystem in real time.

The essence of the method is to identify the parameters of data transmission routes using a rapid GA in which, due to the presence of a special elite population, it is possible to increase the completeness of identification parameters in real time.

The process of obtaining a mathematical description of an object based on experimentally received signals on its input and output is called the identification of the object. The identification can be structural (to search the structure of a mathematical object) or parathrical (for the known structure people find the values of parameters that are the part of the model equation). The construction of a mathematical model of a real dynamic system is possible on the basis of results of either passive or active experiment. Passive identification methods offer the processing of information collected by observing the input and output of an object. Active identification methods offer submission to the input of the investigated object of the trial test signal, the synthesis of which is carried out on the basis of the theory of optimal experiment and processing of the implementation of “input-output”. GA are used to solve the problems of search and optimization, evaluation of the values of uninterrupted parameters of models of volumetric sizes, solving combinatorical problems, optimize models that include simultaneously continuous and discrete parameters. Another area of their application is the use in systems of extracting new knowledge from data bases with a large capacity, creating and training stohastic networks, assessing parameters in the tasks of multidimensional statistical analysis, obtaining initial data for the work of other search and optimization algorithms [6], [12].

Consider the rapid GA in which due to the presence of a special elite population it is possible to reduce significantly the time of searching for acceptable solutions at separate steps of measurements, compared to the classical GA, which makes this algorithm convenient for use in real-time tasks. In this case, a significant part of the time interval between the current measurements is released, which can be used to perform dynamic identification of the system, which must be investigated [7], [13].

Let’s imagine that the process of elements interaction during the work of the genetic algorithm mathes with the functioning of data transmission routes, so the parameters of the algorithm will be considered as the parameters of routes: chromosomes (general delay in the transmission of routes); generation (network routes); population (minimum throughput); genes (reliability); individuals (download).

The genetic algorithm which is being developed consists of several stages Fig. 2.

Introduction of the parameters of the algorithm. First, the basic parameters of the GA are set: NIND – the number of chromosomes for each generation, MAXELIT – the maximum number of elite chromosomes in the population, MAXGEN – the maximum number of generations at each stage of optimization, ε – specified accuracy of optimization of the target function, P_c – the probability of a crossover, P_m – the probability of mutation.

Initialization of the first generation. To initialize the first generation, which consists of chromosomes and equals to the NIND parameter, it occurs by randomly selecting genes, that is, real numbers from a certain area to which the corresponding solution element should belong:

$$B_k^1 \le \theta_k \le B_k^u,\ \forall k \in [1,\ 2, ..., M], \tag{1}$$

where M is the amount of elements (genes) in the solution (chromosome);

B_k^1 and B_k^u are the upper and lower boundaries of the *k* element of the solution.

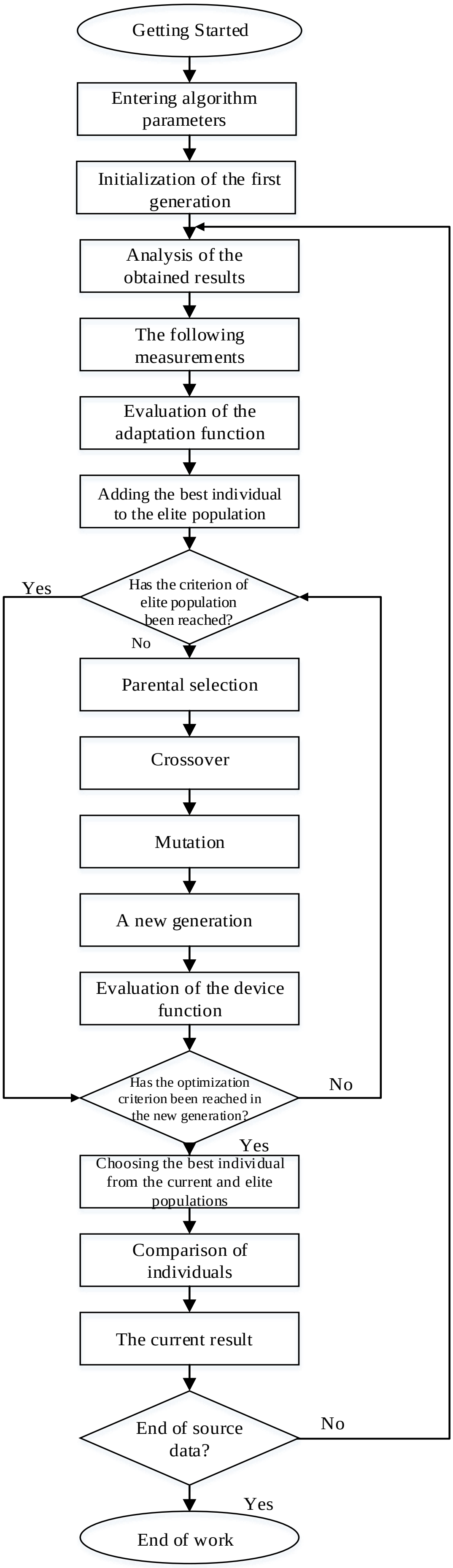


Figure 2 – The scheme of construction of a rapid genetic algorithm

This coding scheme with using the real numbers increases the speed of data processing [8] - [10].

Analysis of the obtained results. It is carried out to identify and recognize initiated persons and populations for the advisability of their further research.

Subsequent measurements. Measurements are carried out to clarify the current values of the target function for solving problems in real time.

Evaluate gadgets. For each person in the current generation, a gadget function based on previously created formulas is calculated.

Adding a better person to the elite population. Elite population, the size of which corresponds to the MAXELIT parameter, during the operation of the algorithm constantly carries out the formation of individuals who have the best functions of the adaptation. On the first step of the algorithm, the elite population can be completely filled with individuals who have the best functions of the adaptation already in the first generation.

If a person from the current population, which has the best function of adaptation, this function has better properties than the current adapting functions of one or more individuals from the elite population, then this person replaces the person with the worst current adaptation functions in the elite population [14].

Checking the criteria of the elite population. The decision to finish the search for an acceptable solution at the current stage of the algorithm research and the output of the obtained results is made if there is at least one such person in the elite population whose adaptation function is better than the accuracy of optimization (ε). If we get several such persons, we choose the one whose function of the device is the best. Otherwise, the search is carried out according to the conditions of the classic GA.

Classic GA. Classic GA consists of the following stages: parental selection (the choice of persons who are the best fitting for creating a new generation); crossover (gene exchange during recombination (performed with probability of P_c)); mutations (accidental change of separate genes, which is designed to preserve the genetic diversity of the population during the work of GA (performed with the probability of P_m)); assessment and formation of a new generation for persons who are part of this generation. For each new formed generation, the criterion responsible for the completion of the optimization process is checked. The criterion is considered to be fulfilled in the following cases, if one person from the current generation has a function of adaptation is better than the specified optimization accuracy (ε), that is, the GA population is ascending; the maximum number of generations has been achieved at this stage of MAXGENT optimization[9], [11].

Choosing the best person from the current and elite population. At this stage, from the elite or current population, we select the person with the best function of the adaptation, which is the result of solving the problem at the present stage of measurements of the real-time algorithm.

Thus, the real-time algorithm at each stage of the measurements is able to provide a positive result that will meet the established accuracy requirements (ε). In some cases, when in the elite population and in all MAXGEN generations of classical GA it is not possible to find a suitable person, this requirement will be violated. From the algorithm diagram (Fig. 2) it follows that when finding a good solution in the elite population, the procedure of classical GA is not performed, and this, in its turn, leads to the release of a significant part of the time interval between adjacent measurements to perform other parallel real-time tasks.

As an example of the use of the contemplative algorithm, consider the problem of identification of a linear dynamic stohastic system:

$$y(k+1) = ay(k) + bu(k) + w(k), \tag{2}$$

where $k = 0,1,...$ – discrete time;

$u(k) = \sin(k/6)$ – known input influence;

$y(k)$ – measured output (system response);

a and b – coefficients of apriori to be identified;

$w(k)$ – white Gaussian sequence with zero mean and some final variance.

Imagine that the true values of the parameters are given: $a=-0,3,\ b=0,4$ and the initial values of variables: $y(0)=0,\ u(0)=0$.

The following basic parameters of GA: $NIND=20;$ $MAXGEN=100; \varepsilon=10^{-5};$ $P_c=0,9;$ $P_m=0,04$.

As a function of adaptation of each chromosome, consider a quadratic function:

$$e_i=\left(y(k)-\tilde{y}_i(k)\right)^2,\ i=1,2...NIND, \quad (3)$$

where i is the number of the chromosome in the generation;

$\tilde{y}_1(k)$ – system output provided from the current model for each chromosome:

$$\tilde{y}_i(k+1)=\tilde{a}_i y(k)+\tilde{b}_i u(k), \quad (4)$$

where $\tilde{a}_i$ and $\tilde{b}_i$ – are current estimates of identifiable parameters (genes of the corresponding chromosomes).

Based on the considered algorithm, we randomly generate the first generation with $NIND=20$ chromosomes, $\tilde{a}_i$ a random number evenly distributed in the range $[-1...0]$, $\tilde{b}_i$ in the range $[0...1]$ according to the formula (1). As for the proposed algorithm, we fill in the elite population with chromosomes with the best adaptation function, which is calculated with the help of formulas (3), (4), then check the criterion for completing the optimization of the elite population. In case of non-fulfillment of this condition, we turn to the work of the classic GA Fig. 2.

The stages of classical GA work on the first steps of measurements of current and paternal generations are set out in Table 1, 2. As an algorithm for selection parents, we use the method of “roulette”, which is based on linear ranking. If this condition is met, all persons of the current generation are initially sorted according to the values of their adaptability function by assigning them a special rating, which is calculated according to the formula [12], [13]:

$$Rank_i=2-SP+2,0\cdot(SP-1)\frac{i-1}{NIND-1};i=1,2...NIND,$$

where i is the person’s number in relation to the generational adaptability function (the person with the worst adaptability function has the number $i=1$, with the best $-i=NIND$);

SP – “selective pressure” parameter in the range of $1.0\le SP\le 2.0$ [12]. This parameter equals to 2, then the person with the worst adaptability function will have a rating of 0, with the best one equals to 2. On the next stage, we select the parent persons from the current generation by “rotating roulette” NIND times. The probability of choosing a suitable person in this case will be proportional to the calculated rating, and not to the absolute value of the adaptability function for the classic “roulette method” [14], [15].

Table 1 – The results of current generation measurement

Current generation $\tilde{a}_i$ $\tilde{b}_i$	Gadget function e_i	Rating
−0,2276 0,5943	1,24e−2	0,1052
−0,8554 0,6367	5,99e−3	0,9473
−0,9058 0,5489	2,37e−3	1,473
−0,3963 0,8742	2,40e−2	0
−0,7527 0,2065	4,00e−3	1,368
−0,6633 0,7183	1,08e−2	0,3157
−0,2503 0,1931	4,58e−3	1,157
−0,1943 0,6337	5,85e−3	1,052
−0,8567 0,3407	3,76e−4	1,894
−0,2044 0,3948	2,82e−5	2,000

Table 2 – The results of parental generations measuring

Selection of parent generation $\tilde{a}_i$ $\tilde{b}_i$	Crossover $\tilde{a}_i$ $\tilde{b}_i$	The resulting generation as a result of mixing and mutation $\tilde{a}_i$ $\tilde{b}_i$	Gadget function e_i
−0,6774 0,6044	−0,6774 0,6044	−0,1943 0,0641	0,0121
−0,9043 0,1557	−0,2396 0,1557	−0,6774 0,6044	0,0045
−0,2396 0,2833	−0,9043 0,2833	−0,5713 0,3407	3,7338e−4
−0,2396 0,2833	−0,2396 0,3948	−0,2566 0,7183	0,0109
−0,2044 0,3948	−0,2044 0,2833	−0,1943 0,6044	0,0045
−0,6633 0,7183	−0,2566 0,7183	−0,0748 0,6337	0,0059
−0,5397 0,6694	−0,5397 0,6694	−0,9043 0,2833	0,0015
−0,1943 0,6337	−0,1943 0,0641	−0,5397 0,6694	0,0078
−0,6774 0,6044	−0,6774 0,6337	−0,2396 0,3948	2,6291e−6
−0,2503 0,1931	−0,2503 0,3407	−0,6774 0,6044	0,0045

The next stage with the probability of P_c a crossover is formed on the principle of "discrete recombination" [10], [16], there is an exchange of corresponding chromosomes in turn between two parent persons who are located next door. At the last stage of the GA work, a mutation is carried out, which is performed with a probability of P_m by the classical method in the form of a set of numbers [7], [10], [17] for further random combinations of individuals in the new generation.

In Fig. 3 is depicted the function of recall of the investigated linear dynamic stochastic system (2) and its prediction on the basis of the current model (4), which are obtained as a result of simulational modeling using the offered GA.

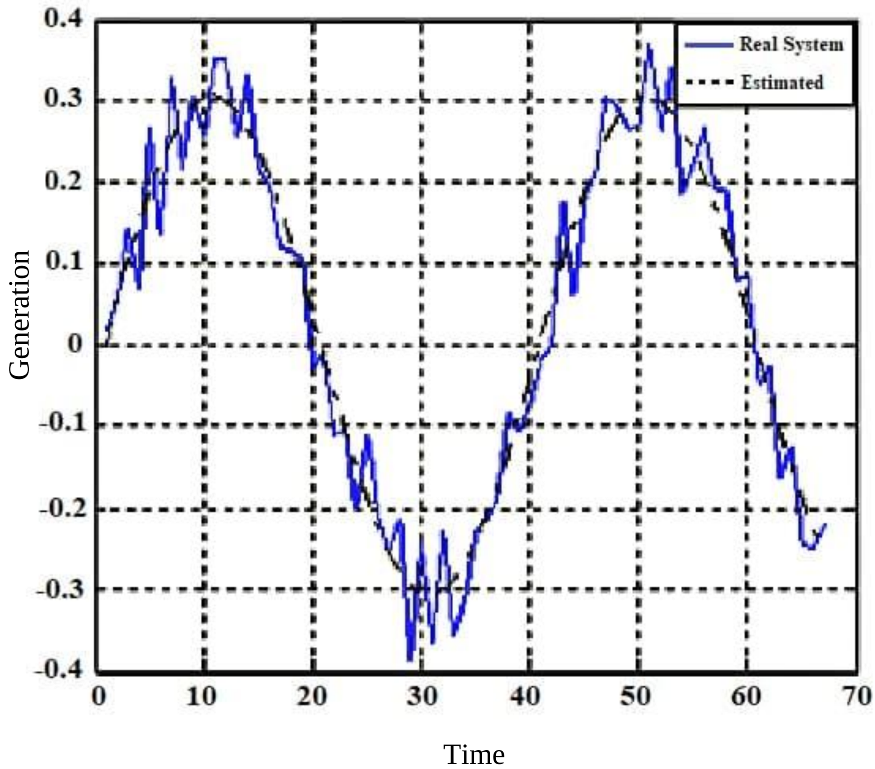


Fig. 3. The function of recalling the investigated system and its evaluation

The results of identifying the parameters a and b of the linear dynamic stohastic system (2) using the proposed GA are shown in Fig. 4. The estimates of parameters obtained during measurements coincide with postulate values as a result of about 30 studies.

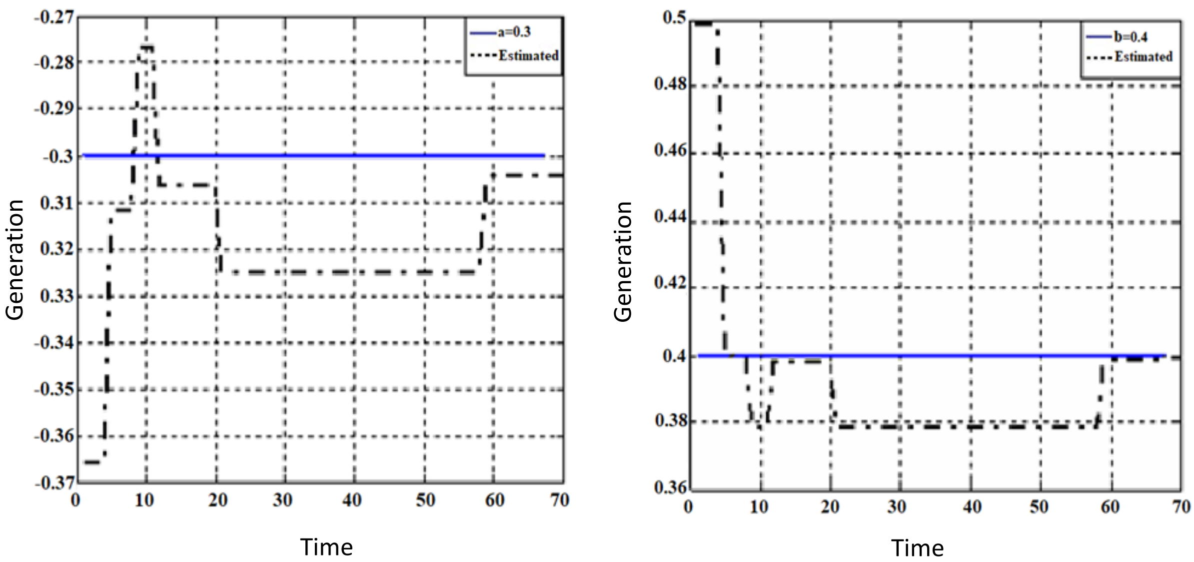
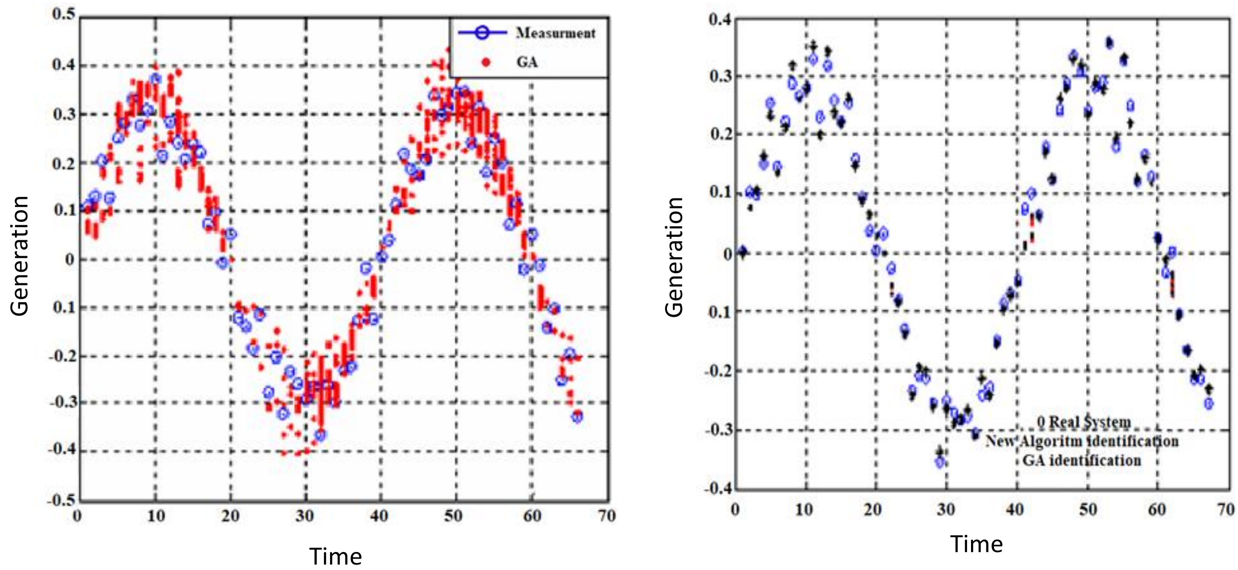


Figure 4 – The results of parameter identifying *a* and *b*

The processes of identifying the linear dynamic stochastic system (2) using classical and rapid GA are shown in Fig. 5.



а б

Figure 5 – Identified GA system: *a* – steep, *b* – classic

Conclusions. Thus, the method for identifying data transmission routes in wireless self-organized networks was developed for the first time. Unlike such methods, identifying a set of route parameters (packages, segments) and not specific WSN data routes, the developed method allows to increase the completeness of identification of route parameters (total route transfer delay, network routes, minimal throughput, reliability, loading) in real time due to the presence of an elite population in a rapid GA , under the conditions of WSN.

This method will allow: to increase the completeness of identification of the parameters of routes of wireless self-organized networks under the conditions of using identification time no more than in existing methods, due to the use of a rapid genetic algorithm.

In the course of further researches, methods for training units and forecasting of the WSN forecasting subsystem will be developed.

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МЕТОД ІДЕНТИФІКАЦІЇ МАРШРУТІВ ПЕРЕДАЧІ ДАНИХ В БЕЗДРОТОВИХ САМООРГАНІЗОВАНИХ МЕРЕЖАХ

Розроблено метод ідентифікації маршрутів передачі даних в бездротових самоорганізованих мережах на основі генетичних алгоритмів. Описано особливості побудови мереж даного класу. Визначено основні завдання функціонування систем управління бездротовими самоорганізованими мережами. Наголошено, що для повноцінного функціонування систем управління бездротових самоорганізованих мережах необхідне підтримання достатньої якості їх обслуговування. Насамперед процес зміни маршрутів передачі даних та прогнозування часу змін маршрутів. Обґрунтовано, що прогнозування дозволяє вчасно налаштовувати мережу для запобігання перевантажень, помилок, виходу з ладу, прогнозувати зміни в маршрутах передачі даних за різних ситуацій. Описаний процес такого прогнозування. З'ясовано, що для вирішення завдань з прогнозування, доцільно використовувати генетичні алгоритми, зокрема задачі багатокритеріальної оптимізації. Це зумовлено принципом багатокритеріальної оптимізації, який полягає в пошуку оптимального рішення, яке одночасно задовольняє більше ніж одну цільову функцію. Описано систему маршрутизації бездротових самоорганізованих мереж, її завдання та особливості побудови. Розкрито модель підсистеми прогнозування бездротових самоорганізованих мереж, акцентовано на її важливості. Визначено поняття ідентифікації, та її методи (активний, пасивний). Розглянуто роботу стрімкого генетичного алгоритму в якому за рахунок наявності спеціальної елітної популяції вдається значно скоротити час пошуку прийнятних рішень на окремих кроках проведення вимірювань, в порівнянні з класичним генетичним алгоритмом. Описані етапи роботи стрімкого генетичного алгоритму та проведені відповідні розрахунки з графічним відображенням. Тож сутність методу, що пропонується, полягає у використанні стрімкого генетичного алгоритму, який забезпечує прийнятну якість ідентифікації невідомих параметрів підсистеми прогнозування бездротових самоорганізованих мереж. З іншого боку за рахунок наявності спеціальної елітної популяції дозволяє значно скоротити час пошуку допустимого рішення під час обробки кожного вимірювання, вмикаючи класичну генетичну процедуру функції оптимізації втрат лише тоді, коли її значення перевищує деякий допустимий пороговий рівень. Даний метод і його реалізація збереже свою працездатність навіть у випадку нестаціонарності підсистеми прогнозування бездротових самоорганізованих мереж.

Ключові слова: ідентифікація маршрутів, передача даних, мобільна радіомережа, генетичний алгоритм, навчання з підкріпленням.

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