Methods of Self-Diagnosing in Telecommunication Networks

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***Abstract*—In the presence of multiple faults (multiplicity no more than *t*) of system diagnostics. The conditions under which the status of each module of the system is determined only on the outcomes of testing modules having physical relation with him (conditions self-definable). The conditions diagnosed systems in cases where for any of the modules is not the conditions self-definable.**

Keywords—telecommunication networks, reliability, self-diagnosing.

I. Introduction

Information about the state of the telecommunications network (TCN) and its components (syndrome of network) can be determined automatically or due to subjective conclusions of the staff on the basis of test data delivered by the central node of the relevant network elements according to the protocols CMIP, SNMP, RMON, NetFlow and others. It uses the principle of "agent-manager", which implements, in fact, the task of system diagnostic testing. Costs of service traffic required for this amounts to 20%, and in some cases over 50%. There is an urgent task to minimize the loss of traffic required for the diagnosis of the quality of the network status. Promising is method of self-diagnosing.

II. The diagnostic model of the structure of TCN

The method of self-diagnosing based on the presence of a reliable check module, with which a survey of states surrounding network elements is made. At the same time the main unit is the results only of faulty network elements.

The technical condition of the system is described by listing clearly faulty modules $K_f = \{i\}$, that make up the so-called image of troubleshooting. The set of admissible faults $K(t) = \{K_f\}$ forms all possible combinations of *M* modules in *m*, where $m = \overline{1,t}$. Many outcomes of tests, which can be obtained for a given image fault K_f is called a syndrome and system status is indicated $\sigma(K_f)$. Let us assume that syndrome $\sigma(K_f)$ is compatible with the image of the fault K_f and K_f generates syndrome $\sigma(K_f)$. For a given $|K_f| = m$ total number of common syndromes with it anyway 2^m.

We denote $E(j)$ as the set of nodes representing the graph in the diagnostic system modules adjacent module *j*; $E(j) = Y(j) \bigcup X(j)$, where $Y(j)$ and $X(j)$ respectively represent modules that test modules that are associated node *j*, and the test thereof. According to the weight of arcs incident to node *j*, we have $Y(j) = Y_0(j) \bigcup Y_1(j)$, $X(j) = X_0(j) \bigcup X_1(j)$. Wherein $Y_0(j) \bigcap Y_1(j) = \varnothing$, $X_0(j) \bigcap X_1(j) = \varnothing$.

III. Terms of self-definable

Define the conditions of self-definable of states [3].

Diagnostic structural model of TCN can be represented oriented circular graph $G = (W, H)$ with a description of the parameters $(M; 1,2,...m,...,t)$, where M - the number of nodes in the network, and $1,2,...m,...,t$. The value of t is called the multiplicity of problems. The nodes of the graph compares the modules and the arc - test relations between them. Weight $u(j,i)$, $j,i \in W$ of arc $(j,i) \in H$ of diagnostic graph (DG) is a binary outcome corresponding to the test: $u(j,i) = 0$, if the module *j* believes serviceable unit *i*, in the opposite case $u(j,i) = 1$.

Suppose that the DG's, the image of the fault K_f and they generated syndrome $\sigma(K_f)$. Each node *j* of DG comparable label $n(j) \in \{\alpha, 0, 1\}$. The analysis of a given node syndrome $\sigma(K_f)$ state *j* can be not identified by ($n(j) = \alpha$), found serviceable ($n(j) = 0$) or defective ($n(j) = 1$).

The process of diagnosing units performed one by one. If identified, the next step of the final status of the node *j*, then further conditions of self-definable for each node $j \in E(j)$ considers the residual plurality $Z(i)$ sets formed an exception to $E(i)$ of the node *j*.

The dynamics of changes in the state of network nodes in the process of diagnosing faults characterize residual image $K_f - f$, where $f = \bigcup_{j \in W} f(j)$ and $f(j)$ - with a plurality of adjacent *j* faulty nodes identified in the preceding steps. In the particular case where $f = \varnothing$ the residual image of the fault coincides with the original. With each node j of the graph self-definable threshold value $\left|K_f - f(j)\right|$ and $\tau(j)$ the value adjustment of the threshold.

The initial state of the graph is defined by the following values listed for each node in the graph [3]:

$$\begin{cases} Z^{(0)}(j) = E(j); \\ \tau^{(0)}(j) = 0; \\ f^{(0)}(j) = \varnothing; \\ \left|K_f - f(j)\right| = t; \\ n^{(0)}(j) = \alpha. \end{cases}$$

During the initial threshold value for all nodes of self-definable accepted value of the multiplicity of faults t, because a priori information about the power of the image is no fault. The threshold varies as the definition of the final status for the new nodes.

On the z-th step of diagnosing, z = 1,2, ..., for each node of the graph, the following transformations [1]:

$$\left[\left|Z^{(z-1)}(Y_1(j)) \cup Z^{(z-1)}(X_1(j))\right| > \left(t - \tau^{(z-1)}(j)\right)\right] \to n^{(z)}(j) := 1 \quad (1)$$

$$\left[\left|Z^{(z-1)}(Y_0(j))\right| \geq \left(t - \tau^{(z-1)}(j)\right)\right] \to n^{(z)}(j) := 0 \quad (2)$$

$$n^{(z)}(j) := 0 \to \left[\forall i \in X_0(j)\{n^{(z)}(i) := 0\}\right] \& \left[\forall i \in (Y_1(j) \cup X_1(j))\{n^{(z)}(i) := 1\}\right], \quad (3)$$

$$n^{(z)}(j) := 1 \to \forall i \in Y_0(j)\{n^{(z)}(i) := 1\}. \quad (4)$$

$$n^{(z)}(j) := 0 \to T(j) := Y_1(j) \cup X_1(j); \quad (5)$$

$$\forall i \in (E(j) - Y_1(j) - X_1(j) - X_0(j))\{f(i) := f(i) \cup T(j); \tau^{(z)}(i) := |f(i)|\}$$

$$n^{(z)}(j) := 1 \to T(j) := Y_0(j) \cup j; \quad (6)$$

$$\forall i \in (E(j) - Y_0(j))\{f(i) := f(i) \cup T(j); \tau^{(z)}(i) := |f(i)|\};$$

$$Z^z(i) = E(i) - \{j \cup Y_0(j)\}, \quad \text{if } n(j) = 1, \quad (7)$$

$$Z^z(i) = E(i) - \{Y_1(j) \cup X_1(j)\}, \quad \text{if } n(j) = 0.$$

There $n(j) := s$ - node assignment operation j marks the final condition $s \in \{0,1\}$. Expressions (1)-(2) signs indicate the final status of the node based on the values of the syndrome, related only to itself. Expressions (3)-(4) shall indicate the conditions of installation of the final status of adjacent nodes, which is a consequence of the identification of the final status of the node j according to (1) and (2). Transformations in (3)-(4) follow the rules determining the outcome of testing for the model Preparata-Metz-Zheng (PMZ), according to which $\left[X_0(j) \subset (W - K_f) \& [Y_1(j) \cup X_1(j)] \subseteq K_f\right]$, if node j is serviceable and $Y_0(j) \subset K_f$ if node j is defective. In the expressions (5) and (6) set the conditions for adjusting the threshold of self-definable for node j, $T(j)$ and $f(i)$ - lists that map nodes j and i, respectively. Expressions (7) determine the residual sets for sites that are not switched to the z-th step in the final state.

Node called self-definable if at a given syndrome recursive application of (1)-(7) to a graph completed its installation in the final state. The residual image of faults $K_f - f$ self-definable called if and only if for any joint syndrome with him at least one node *W-f* of a self-definable. Otherwise, the image of the fault and state of graph as a whole are called deadlock.

Terms of the local t-diagnosability and determination values t_z are given in [3].

IV. The Method of Implementation of the Principle of Self-Diagnosing TCN

For optimum implementation of consistent implementation of the various checks of the test unit tests the different nodes of the system is based on the DG Hamiltonian path, which, by definition, comes in every vertex once. If the initial and final vertices of this path are the same, then the path is built Hamiltonian cycle (HC). For a homogeneous system intact DG such a cycle is always there. For the method described below is enough to choose any HC to evade all vertices DG working configuration (WC) system intact. This cycle is selected once the design of the control system.

For information on the composition of the selected WC № v n-OU system represented as a table H_{Cv}.

It consists of m strings $H_{jv},...,H_i,...,H_{nv}$, in each of which a node $n_i(i = j_v,...,m_v,$ where $0 \leq i_v,...,m_v = m+ +n-1)$ recorded numbers successor nodes n_{l1}, n_{l2}, (adjacent node n_i), it also has a cell to record the results n_i of these test units $z_{i,l1}$, $z_{i,l2}$, and unit values of their number in the ranking of the graph. An example of such a table H_{C0} built for the WC №0, comprising 8 lines, is presented in table 1. As can be seen from table 1 - for each of its cell line filled only for the tested node n_i and its successor node test - $n_{l1},...,n_{l3}$.

To display the location of nodes in the HC will be written in assembly line H_i of successors of node n_i, so that it node n_{l1} is a neighbor of the node n_i in the right in built cycle. For WC №0 selected a HC $0 \to 1 \to 3 \to 2 \to 6 \to 7 \to 5 \to 4 \to 0$ in this order in the table 1 line H_i are recorded.

The monitoring process starts by diagnostic monitor (DM) at regular intervals to prevent the accumulation of failed elements in the system and contributes to achieving the target of inerrancy.

Assign the initial vertex of the control one of the vertices of the selected HC and denote her n_m. In this case, the signal DM tester node n_m must perform these steps:

TABLE I. TABLE OF COMPOSITION H_{C0} FOR WC №0

The symbol of string	The check module and the rank		The successors n_i, results of their checks and the rank								
	n_i	*rank* n_i	n_{l1}	$z_{i,l1}$	*rank* n_{l1}	n_{l2}	$z_{i,l2}$	*rank* n_{l2}	n_{l3}	$z_{i,l3}$	*rank* n_{l3}
H_0	0	-	1	-	-	2	-	-	4	-	-
H_1	1	-	3	-	-	5	-	-	0	-	-
H_3	3	-	2	-	-	7	-	-	1	-	-
H_2	2	-	6	-	-	0	-	-	3	-	-
H_6	6	-	7	-	-	4	-	-	2	-	-
H_7	7	-	5	-	-	3	-	-	6	-	-
H_5	5	-	4	-	-	1	-	-	7	-	-
H_4	4	-	0	-	-	6	-	-	5	-	-

1) mark the string H_m the table H_{Cv}, found in her numbers successors n_{l1}, n_{l2},...; check their technical condition and in the cell $z_{m,l1}$, $z_{m,l2}$, of string H_m to record the results of checks in binary: 1 – correct, 0 - suspected failure;

2) to evaluate the results of the checks:

a) if $z_{m,l1} = 1$, then transfer control to the process control node n_{l1};

b) if $z_{m,l1} = 0$, but if one of the other results (for example, $z_{m,l2}$) - 1, then transfer the management control of process to corresponding node (node n_{l2});

c) if the verification of all the successors n_m have produced results 0, the control process should start with another node.

Node $n_1(n_{l1}, n_{l2}, ...)$ and each of these units perform the same actions. This inspection process and passing the selected cycle ends at the moment when the control is returned to the original node $n_m(n_{m2})$. Such a deterministic way around the vertex of the graph is only possible when working order of all elements audited WC. If at any stage of testing produced zero results, which indicates the detection of one or more failed elements, the control process is terminated, and DM self-diagnosing proceeds to the process:

a) execution of a serviceable unit testing node functions;

b) finding a serviceable way from one node to another, possibly through appropriate procedures ranking serviceable units;

c) c) processing and decoding the results of tests performed.

These procedures are implemented by a set of serviceable units WC №*v*. The need for the execution of all or part of the testing procedure is determined by the next node based on the results of checks carried out by him and the information that was received from the previous node.

The methodology adopted by the procedure PMZ [2]. As a result, the state fails to identify faulty network element on the basis of a comparative analysis of the outcomes of testing only the adjacent network elements and without the involvement of data on the status of other network elements.

As a result, the diagnostic model can be represented as a structure representing tsirkulyativny graph with *N* vertices and vertices of degree *t* for the survey of the organization of mutual nodes fails to provide identification of the network that has the number of faulty nodes, the multiplicity of which does not exceed the value of *t*. The limiting ratio is $N \geq 2t + 1$.

For fault localization procedure should be used for decoding the syndrome test results.

Many test is weighted directed graph *G* (*Q*, *A*) without loops whose vertex set is the set of modules and each arc $a_{sj} \in A$ exists when the vertices q_i, q_j take part in the performance of the same test. The direction of the arc a_{ij} from the vertex q_i to the vertex q_j means that the vertex q_i check to vertex q_j and the weight of this the arc (boolean variable e_{ij}) is a decision made by checking the apex.

The stability of failures vertices - each vertex in the performance of the tests can be in one of two states: an efficient or denied. We consider only parallel *t*-diagnosing.

Matrix of scales of arcs of graph represents syndrome $\alpha = \{e_{ij} : (i, j) \in A\}$. The set $N \subseteq Q$ of vertices of faulty $N \subseteq Q$ image faults. For every F is true: $|N| \leq l$.

Local referee - the vertex $q_n \in Q$, the ability to identify at least one element of the set $dg \in N$ based on the weights of outgoing paths *c* of length ≥ 1.

Local judge - the vertex $q_n \in Q$, the ability to identify all elements of *N* on the basis of the balance of outgoing arcs.

The diagnostic model is described by the quartet, which determines the rules of generation of weights of arcs:

e_{kk} – decision taken by the workable vertex checking on the state of the audited workable vertex;

e_{kh} – decision taken by the workable vertex checking on the state of the audited refused vertex;

e_{hk} – decision taken by the refused and checking vertex on the state of the audited workable vertex;

e_{hh} – decision taken by the the vertex refused to check on the state refused to check the vertex.

$e_{kk} = 0; e_{kh} = 1$. It is assumed that $e_{kh}, a_{hh} \in \{0,1,-\}$, where the symbol "-" means unpredictable (0 or 1) the result of the simple test. For example, PMZ-model [2] is defined by quartet 01--, BGM-model correspondingly quartet 01-1.

Of practical interest are the state of 0111 and 0110. As shown in [4], the state of 0111 can describe the tests that are based on the inspection results of a match the same transaction multiple nodes of the system. When this assumption is the basis is the impossibility to obtain the same results of the same operation a pair of identical units under the condition identical output data in case of failure of even one of these nodes.

Model 0110 can also describe testing which are based on the verification results match perform the same operation several units of the system provided the possibility of obtaining the same results at the same output in the case of efficiency or failure of both units.

Obviously, using the methods of self-diagnosing it is advisable to go for decentralized monitoring methods when the results of testing the status of individual network elements are concentrated in the network nodes and the central node receives a generic report that contains information only on the detected critical states. This arrangement minimizes the monitoring service traffic on the order.

V. Conclusions

1. The conditions for the completeness and correctness of the local *t*-diagnosing of TCS in the case where the image generated by the fault and it's syndrome lead to deadlock - the inability to use the conditions imposed of self-definable to identify the actual state of the modules.

2. An algorithm for identifying the specified image of self-definable fault for arbitrary values of *M* and *t*.

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