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MODELING SURVIVABLE INFORMATION NETWORK

In the article the basic steps of creating a model of building survivable network information have been considered.
Keywords: network modeling, survivability, fault tree, Markov graph.

Over the last years we can observe giperincreasing of society's dependence on information systems and all kinds of digital communication systems, which usually can be associated with computer networks, implemented in the form of local, corporate, and global distributed systems, and mobile communication systems. Therefore, the requirements have been increasing for the provision of basic functions - confidentiality, integrity and availability of information, where crucial significance has vitality of the system.

Under the vitality of modern security systems we mean the ability of providing health information system under the influence of destabilizing factors and operating conditions [1,2].

The concept of survivability used in engineering in the design of technical systems differs for the systems of the protection of information systems and has its own characteristics. Up to now, no theory has been developed that would allow investigate features of survivability of information systems to manage, monitor and evaluate the viability of such systems.

At present, the theory of survivability has not effective proposed mathematical models of survivability, proven in practice, there is no common scientific understanding of quantitative indicators of vitality, there are no methods of estimation and survivability.

In the papers [3-5], a modeling system of survivability based on the modeling of intellectual systems from the perspective of system analysis based on the theory of decision making, has been proposed.

In this paper, as an initial describing of the network we will use the logical-probabilistic model of fault trees (FT), which gives the compactness of the job of the model (for example, compared with Markov graphs).

1. In the process of modeling it is necessary to make some steps: at first it is necessary to determine the primary node, the failure of which most significant influences on the behavior of the network, translating it into a state of complete or partial failure.

2. Then to determine all states of the primary node, and to analyze ways of transitions in possible system states of failure under a fault condition of other network elements for each event. On the basis of new date to build a close-up on IR n main branches, which in accordance with the n are dedicated non-generic events.

3. The next step is building a model that takes into account the different aspects of the events of failures of network components.

4. On the basis of these models we build Markov transition graph in the state space of the main body and the identification of appropriate reliability stay in the states. The Markov model is used to register the characteristics of the control, different ways of reserving multiple failure modes. Transition intensities of a Markov model are determined taking into account the

settlement failures.

5. Building a «nested» tree that detail the transition to failure (failure) of the network for each non-public events (state primary host.) The calculation of the reliability of the corresponding vertex events. The initial parameters for the viability of basic events are determined by the settlement failures.

6. Setting the initial parameters of the vitality of the basic events of the tree close-up on the basis of calculations of the Markov model and the nested trees. Calculating performance of the whole network survivability.

Note that the aggregation of static and dynamic models can be performed on a system-wide static model, in particular, the failure of the trees, the functional integrity of the schemes, the introduction of new dynamic vertex operators and without implementing decomposition network. As part of the qualitative analysis of defined sets of minimum intersections.

As a result of the quantitative analysis, we obtain numerical values of the following indicators survivability:

- degree of availability / unavailability
- the accuracy of fault / trouble-free operation of work
- failure flow parameter,
- mean time between failures,
- the average time renewal
- the average number of failures in a given time interval.

In foreign software are mainly implemented methods of calculating, based on a theorem about the reliability of the sum total of events (in this case, under the event refers to the implementation of minimum intersection):

$$Q(t) = \sum_{i=1}^{n} P_r\{C_{i_1}\} - \sum_{i_1=1}^{n-1}\sum_{i_2>i_1}^{n} P_r\{\bigcap_{j=1}^{2} C_{i_j}\} + (-1)^2 \sum_{i_1=1}^{n-2}\sum_{i_2>i_1}^{n-1}\sum_{i_3>i_2}^{n} P_r\{\bigcap_{j=1}^{3} C_{i_j}\} + \ldots + (-1)^{n-2} \sum_{1\le i_1<i_2<i_3<\ldots<i_{n-1}\le n} P_r\{\bigcap_{j=1}^{n-1} C_{i_j}\} + (-1)^{n-1} P_r\{\bigcap_{i=1}^{n} C_i\}, \quad (1)$$

where Q(t) - the accuracy of the occurrence of the top event tree, Ci - i-th intersection minimum, n - sum intersection minimum. For the accuracy of the fault tree Q(t) is the ratio of unavailability, and success for the tree - the coefficient of readiness. Difficulties arise in the calculation of the interval confidence metric uptime for recoverable networks.

In this case the reception is generally used when the system is unrecoverable artificially to give a lower bound index.

An approximate formula has been proposed for the calculation of the reliability of fault-free operation of renewable networks, the numerical solution of which is well automated and provides the results of the required accuracy of adaptive quadrature algorithms

$$P(t) \approx e^{-\int_{o}^{t} \frac{w(\tau)}{K(\tau)} d\tau} \quad (2)$$

где, P(t) – the accuracy of the fault/trouble-free operation, w(τ) – parameter stream of refusals, К(τ) – degree of availability/unavailability, dτ – mean time to recover.

Then we create a dynamic fault trees through the introduction of dynamic vertex (which we use as operators), we define a set of dynamic and static nodes that allow you to build an adequate model of survivable information network (SIN). The procedure of use of n-inputs dynamic statement, the occurrence of input events in the interval (0, T) с the recurrence of the integral equation, which takes into account the sequence:

$$Q_n(T)=\int_0^T f_n(\tau)\cdot Q_{n-1}(\tau)d\tau$$
$$Q_2(T)==\int_0^T f_1(\tau)(1-F_2(\tau))F_2(T-\tau)d\tau \quad , \qquad (3)$$

where, $Q_n(T)$ - the accuracy of the sequential occurrence of n-inputs events of the operator (from left to right); $F_i(t)$ and $f_i(t)$ - distribution function and the probability density function of time since the onset of the i-th input event. The use of this integrated model (3), instead of the Markov model, allowed us to remove the restriction on the proportionate distribution function.

Then we solve the problem of representing FT data structures that allow traversal speed and getting the logic function failure (efficiency), which is displayed in a tree orthogonal disjunctive form as:

$$f = Y_1 \vee Y_2 \vee \ldots \vee Y_m, \quad \text{где} \quad Y_i \wedge Y_j = 0 \quad \text{для} \quad i \neq j;$$

where, Y_i - nonrecurring basis in the form of a conjunction-negation.

Quantitative analysis FT is a difficult task for a programmer, because it requires the development of fast algorithms for generating sets minimum sections and complex coding procedures, the expression (6). The newest trend in automated reporting and conversion of Boolean functions is to attract modern, efficient methods of discrete mathematics. The desired representation of the logic tree is proposed to use binary decision diagrams.

In terms of binary decision diagram logic functions are represented as a directed acyclic graph, whose interior vertices are the arguments to the function. As well distinguish two types of end nodes designated as 0 and 1. Each non-leaf node has two successors. The branches of the graph are ordered - when you click on the left branch of the argument is set to 1, when you click on the right - the value is 0. The value is determined by the logic function descent from the root to the terminals.

When you automate tasks survivability important advantages are diagrams of binary decisions:

- presentation of the logic functions in an orthogonal form of transition to be replaced, the logical variables that allow for a replacement, likely and logical operations - arithmetic. This is achieved by the fact that the very principle of the binary decision diagram provides a logical expansion of functions into orthogonal components.
- For computer implementation diagrams of binary solutions is non-linear dynamic data structure - a binary tree, which is designed for efficient traversal algorithms whose complexity depends on the number of levels of the tree, i.e., about $\log_2 n$ (where n - the number of nodes).

The use of binary decision diagrams and the principle of aggregation in software allows us to offer the following procedure quantitative analysis of fault trees that contain dynamic peaks, simulating specific features of "enduring behaviors" that are not covered by the model of universal programs:

- define the structure of a tree in a graphics editor universal software using the COM-technology or import data.
- Perform an analysis of each object passed to the ownership structure of the groups: the basic events, complex events (sub-trees), the static vertex (AND, OR, NOT), simple dynamic top of the inputs, which consist only of the basic events, dynamic peaks, all or part of the inputs which are the other vertices of the tree (complex dynamic vertex).
- Calculate the unavailability of fixed coefficients (availability $K(\tau)$) and stream of re-

fusals parameter ω for simple dynamic peaks. Next, determine the mean time between failures $T_м$ and recovery times $τ_в$ from relations $T_м = K(τ)/ω$; $τ_в = ((1- K(τ))T_м)/ K(τ)$ and replace each vertex equivalent to the basic dynamic event, the time of occurrence of which is distributed asymptotically exponentially with the failure rate $λ=1/T_м$ and renewals $μ =1/τ_в$.

- carry out a similar reduction of complex dynamic peaks, consistently replacing the simple dynamic peaks and embedded trees equivalent to the basic events and get the result tree, which consists of the "classic" nodes (AND, OR, NOT).
- the resulting tree diagram to convert to binary decisions and carry out the required qualitative and quantitative analysis.

An algorithm for converting DV to binary decision diagrams:

- Sort the basic event tree: $x_1<x_2<\ldots x_n$
- Each i-th basic event associate the top three **(x_i, *1, 0*)**
- Each node of the tree failures associate the operator $F_i\ (x_j, f_{i1}, f_{i0})$, determined in accordance with:
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$$F_i * F_j = \begin{cases} if\ (x < y) \Rightarrow (x, f_{i1} * F_j, f_{i0} * Fj) \\ if\ (x == y) \Rightarrow (x, f_{i1} * f_{j1}, f_{i0} * f_{j0}) \end{cases},$$

$$\text{where}\quad F_i = (x, f_{i1}, f_{i0});\quad F_j = (y, f_{j1}, f_{j0}) \tag{4}$$

$$if\ \begin{cases} * = AND, \text{ that } 1 * F_j = F_j;\ 0 * F_j = 0 \\ * = OR, \quad \text{that } 1 * F_j = 1;\ 0 * F_j = F_j \end{cases}$$

Consistently applying the rules, get the "algorithmic convolution" operators for the top event of the fault tree

$$TOP = G_1(\underbrace{x_1}_{\text{root}}, \underbrace{(x_k, g_{j1}, g_{i0})}_{\text{branch for } x_1==1}, \underbrace{(y_k, h_{j1}, h_{i0})}_{\text{branch for } x_1==0}) \tag{5}$$

- Consistently revealing "single" and "zero" components, to form a binary tree,
- Evaluate the accuracy of the vertex of the initial events of the fault tree as the sum of the reliability of paths that lead from the root of a binary tree to a terminal node "1".

Then analyze the information network with survivable “failureresistance”. In the form of a basic block of the network we will take three concurrent servers that have two triples communication devices (NICs).

Networking allows you to receive information from the external environment and its distribution in the network. During operation of the network in the event of malfunctions (component failure), it deteriorates. Degradation occurs on a difficult "path", which is the initial state three-server configuration, and the end - the states corresponding to system failures.

In the process of degradation of the network can take two-server configuration with a blocking third server and a single-server, in which one server communicates with the external environment, the second operates on a "listening" (control) server running, and the third is blocked.

There are two possible failure of the system as a whole - a failure, in which the system gives priority to the environment safe shutdown command, and dangerous failure, which does not provide delivery of safe shutdown command, and the external environment, or it does not accept control commands from the system, or the system produces incorrect instruction.

The reaction of the network to the problem that has been arisen is organized as follows.

If you violate the normal operation of the network as a result of failure or malfunction of its structural elements (servers) this element programmatically is removed from the running configuration. The decision about the possibility of future use of the excluded element is taken on the basis of two criteria. The first criterion ("Frequency"): non-working item is recognized if, before the end of the specified interval Δt will additionally be recorded ($m_{кр}$-1) disruption to this element. The second criterion ("sequential") element is recognized as such, that has failed, if after the first violation of its functioning violations will occur more ($m_{кр}$-1) times in a row.

Using the Poisson approximation to the binomial distribution it is possible to determine the expression for the reliability of the recognition of the fault element of failure in the interval (0, T) over a frequency criterion as:

$$P_{сб}(T) = \left[1 - e^{-\lambda_{сб}\Delta t} \frac{(\lambda_{сб}\Delta t)^{m_{кр}}}{m_{кр}!} \right]^{\left]\frac{T}{\Delta t}\right[}. \quad (6)$$

where, $\lambda_{сб}$ - rate of flow disruptions.

The accuracy of the recognition of the failure of component failures on the basis of "consecutive" criterion was derived using the theory of finite Markov chains [6]:

$$P_{сб}(T) = e^{-(\frac{T}{T_{cp}})},$$
$$T_{cp} = M\lfloor f_{m_{кр}+2} \rfloor \Delta t, \quad (7)$$

where, T_{cp} - the mean time to first occurrence of the initial operating state to the absorbing state circuit corresponding $m_{кр}$ unsuccessful attempts to perform a given function. $M\lfloor f_{m_{кр}+2} \rfloor$ - average number of steps.

Reliability Q(t) recognition element of a computer system on the interval (0, T) is defined as the failed [7]:

$$Q(T) = 1 - P_{отк}(T)\, P_{сб}(T), \quad (8)$$

where, $P_{отк}(T)$ - the accuracy of the fault-free operation of the cell at constant refusals; $P_{сб}(T)$ - the accuracy of the recognition that the failure of a component is due to failure. $P_{сб}(T)$ is calculated by (6) or (7) depending on the criteria of recognition.

For the threeserver survivable network information with frequency and consistent criteria for the recognition of components that fails or refuses, we construct a hierarchy of nested dynamic fault trees, Markov model is implemented survivability triple block servers with the incompleteness of the control and distribution of the failure modes of the dangerous and safe, the correction accuracy implementation of the basic events in the fault tree models that performs a "screening" flow disruptions special software to implement procedures for handling failures [8].

The developed model enabled to make a calculation of indicators of survivability information network and to give recommendations on the choice of parameters of computational procedures for the reduction process, broken by the problems with different ratios of the intensities of failures and permanent failures of network elements.

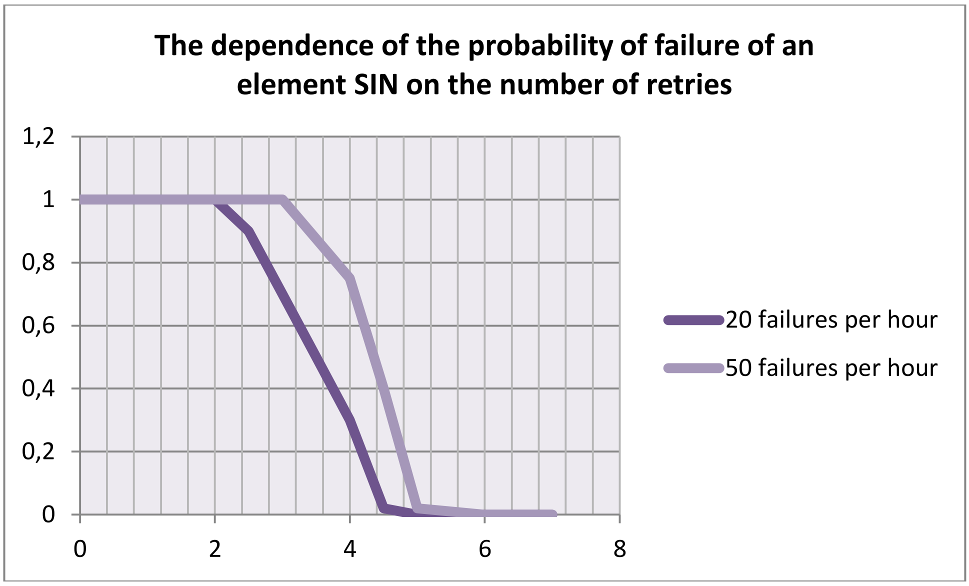

Fig.1. A plot of the probability of failure element SIN on the number of retries

A plot of the probability of failure of element SIN on the number of retries in the interval (0,10000 hours) to $\lambda_{сб}$ = 20 1/h and $\lambda_{сб}$ = 50 1/h at a fixed failure rate equal to $2{,}34 \bullet 10^{-6}$, is shown in fig.1. The graph shows that a small number of retries (<4) failures define low reliability of the system. As the number of retries (> 5) failures do not affect the reliability of the system, which in this case is completely determined by the flow of permanent failures.

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МОДЕЛЮВАННЯ ЖИВУЧОЇ ІНФОРМАЦІЙНОЇ МЕРЕЖІ

У статті розглядаються основні етапи створення моделі побудови живучою інформаційної мережі.

Ключові слова: мережа, моделювання, живучість, дерево відмов, марківський граф.

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МОДЕЛИРОВАНИЕ ЖИВУЧЕЙ ИНФОРМАЦИОННОЙ СЕТИ

В статье рассматриваются основные этапы создания моделии построения живучей информационной сети.

Ключевые слова: сеть, моделирование, живучесть, дерево отказов, марковский граф.