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THE SYSTEM RESEARCH OF RELIABILITY INDEXES OF INFOCOMMUNICATION NETWORKS WITH DISTRIBUTED STRUCTURE

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Abstract: In this article the questions of the system research of reliability indexes of the infocommunication network with distributed structure are considered. As a criterion proposed use the reliability index, based on reliability state of each level of the considered network. Showed that development of methods and algorithms of system research of reliability indexes of the infocommunication network in terms of workload of its components is one of the main problems in the design of network with a complex structure. The model that allows a system approach to research the reliability indexes of the infocommunication network are proposed. The infocommunication network with a distributed structure are introduced as a system consisting of K interacting subsystems (level). The main factors of reliability state of equipments (gateways, routers, switches, Softswitch and other) of each lever are described by vector-functions. By these vector-functions given own reliability operators of infocommunication network.
Keywords: infocommunication network, next generation network, quality of service, softswitch, reliability, coefficient of availability, coefficient of downtime, reliability processes, index of reliability, stationary coefficient of availability, time to failure, reliability state, vector-function, functionality of network, reliability operators, communication channels.

Introduction

Functional model of modern infocommunication network (IN) with a distributed structure (or a next generation network-NGN) model can be represented by 4 levels: the level of access; the level of transportations of data (transport layer); the level of network management; the level of service management (Fig.1) (ITU-T Recommendation Y.2001).

At the level of the access edge connect is subscriber and terminal to the network on the basis of the application of various machine-tools and a transformation format of output data in the appropriate format used to transfer in the transport network. At the transport level, by providing customers a consistent and integrated platform of information transmission with high reliability and high quality of service (QoS). At this level routers and IP switches, which are located in different points of the transport network and are connected via the trunk channels with large enough bandwidth capabilities (Semyonov, 2005).

The main task of the level of network management is to ensure flexible switching, that is used for call control and manages the installation of connections in real time. Softswitch is the main device, effecting the level of control switching and transmission of information. At the management level of services is mostly the offer services and support of functioning of the network at a set of connections.

A characteristic feature of IN with distributed structure is the heroine: the use of packet technology for transferring all types of information; application of commutation systems with distributed architecture; the division of functions support services from switching and transmission; ensuring the opportunities of broadband access for any user; realization of functions of the operational management through Web technologies (ITU-T Recommendation Y, 2011).

Thus, the modern infocommunication network (IN) with distribution structure, as a complex hardware and software system consists of the means of communication and switching, and from the funds of processing and storage of information, and from the means of control of network resources, and performs the functions of providing various types of services and adoption of decisions for a quality service user requests.

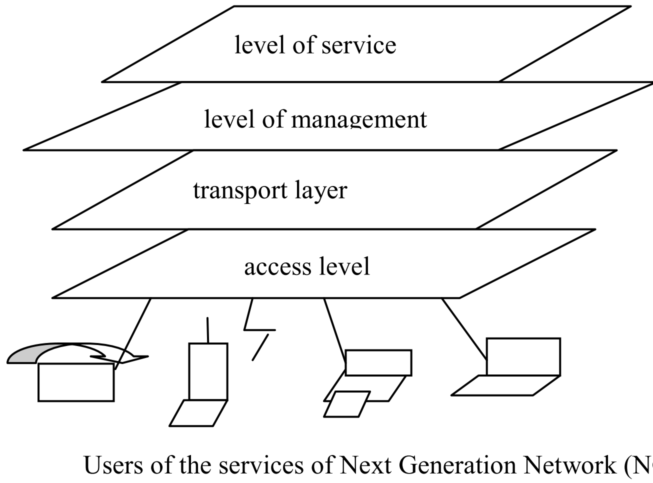

Fig. 1. The basic architecture of modern infocommunication network

The main requirement for IN is timely great service for all types of applications users at a high qualitative level, in the given time and with minimum costs. The user is not important, as is the service provided and through which the road crosses each transmitted packet of information. The most important thing for it is the timely receipt of the required services and with a certain level of quality service provision.

When requests of users, as a rule, involves all the components of IN and inefficient functioning of at least one network element can bring all the work of other components of the network. The emergence of failures and failures in network television and gateways, routing and switching centers, systems of processing and storage of information, and also in systems of control of network resources results to break of normal operation, both operators and users (clients), which leads to large losses of companies providing various services.

Statement of a problem

Growth of requirements to the quality of the functioning of the IN by users, and increased competition between network operators, also spend all operators pay more attention to the parameters, which characterized quality of service (Quality of Service, QoS). And reliability is one of the most important factors affecting the QoS, therefore requirements to reliability of the functioning of the IN, are one of the main indicators of quality of service user requests. It is well known that the reliability is a property of the object to keep within the established values of all parameters and the ability to perform its required functions under stated conditions and modes of application.

Reliability of the IN has two aspects. The first is the reliable functioning of its parts. Second is the ability of the network to continue to function at refusal of its individual sections. The first characteristic of reliability is determined by the coefficient network readiness to work. The second characteristic of structural solutions that allow traffic to select routes and treatment system, bypass the failed components of the network (Cherkesov, 2005).

Availability of all IN equals the product of coefficients of readiness of its parts. In the presence of linear structures, to work IN is critical uptime switching devices, communication channels, processing systems and system software needed to transfer, processing and storage of data. Coefficient of availability is calculated as the ratio of the time of standing idle object to the total observation time. In the ideal case, the coefficient of availability readiness must be equal to 1 that means 100% readiness of the network. In practice, the coefficient of availability is evaluated by the number of “nines”. If the willingness of the IN assessed the value of the “five nines”, this means that the network 5.5 minutes standing idle in the year.

Coefficient of availability $K_Г$ is the probability that the network will be operable in an arbitrarily chosen point in time:

$$K_Г=T_o/(T_o+T_B),$$

where T_o is the mean time between failures(MTBF); T_B – average time of restitution of operating state.

Coefficient of downtime (coefficient of unavailability) of $K_П$ is the probability that the network will not be able to work in an arbitrarily chosen point in time: $K_П=1–K_Г$.

To the coefficient of availability affect four factors: refusal of the equipment and software; automatic protection switching; methods and technological discipline operation; characteristics of the communication channels and protective measures. In reality, when designing IN can be used some other modifications $K_Г$.

Unsteady coefficient of availability is the probability that IN will be workable in the given moment of time is counted from the beginning of work (or from other strictly a point in time), in case, when known to its initial state. The average coefficient of availability averaged over a given interval of time value of unsteady coefficient of availability. Stationary coefficient of availability (coefficient of availability) – the probability that the recoverable component IN will be employers capable of arbitrarily chosen point in time in a steady process of exploitation.

Quantitatively the second characteristic of reliability of IN is defined by «time to failure». Time to failure is the probability that within a given developments denial of IN not have (provided health at the initial moment of time). Mean time to failure – the mathematical expectation of random developments object till the first failure. Mean time between failures – the mathematical expectation of random developments components IN between failures (Jin and Coit, 2003).

Given time – time during which the IN must be work non-failure for the performance of its functions. The average downtime is the mathematical expectation of random time of the forced non-time limit the ad hoc stay IN in a state of failure. Average recovery time – the mathematical expectation of random length of recovery (actually repair).

The probability of recovery is the probability that the actual duration of the recovery of the object does not exceed a given. The coefficient of maintain efficiency – an index, characterized influence of the degree of reliability to the maximum possible value of the indicator (i.e., the underlying state full functionality of all components of the IN).

With the development of IN share of operating costs increases, also there is a continuous increase in the number of users, leading to increased load on the network and inefficient functioning of its components may lead ultimately to the failure of QoS requirements, the growth of probability information loss and the probability of dropped calls was reduced etc.

In this regard, the development of methods and algorithms of system research of reliability indexes of the infocommunication network in terms of workload of its components is one of the main problems in the design of IN with a complex structure (Musayev and Skvorsov, 2008). Below is a model that allows a system approach to research the reliability indexes of the IN.

Problem decision

Imagine the infocommunication network with a distributed structure – as a system consisting of *K* interacting subsystems (level). The network has *n* inputs and *m* outputs. The inputs IN come under terms of it work useful effects (physical input signals, the tasks to be performed, the control commands etc) or harmful impacts (noise, vibration, high temperature, humidity etc) affecting its credibility, and each entrance is designed for the impacts of the same type (Musayev and Skvorsov, 2008).

The outputs of the IN removed different results of its operation (processing-on signals, solved problems, executed commands provided by different types of services etc), and each output characterizes someone function (result of work) network.

IN seems to be hardware performance (gateways, switches, routers), algorithms of functioning of flexible switchboards (Softswitch) and their reliability characteristics, identified given specified structure of the network protocols of data exchange and the characteristics of the communication channels.

External impact (noise, noise, atmospheric influence, unsanctioned access and other factors) have a direct impact on domestic input network settings. New solutions, introduced in the process of exploitation is on the new network, also affect its internal parameters.

Reliability state (RS) on the inputs of the various gateways level of access is set by the vector $X(t)$:

$$X(T) = [x_1(t),\ x_2(t)\ \dots,\ x_n(t)\ ],$$

where $x_i(t)$ is a continuous function of time t, describing the change of reliability status of the i-th input, that is, describes the nature of the impact on the i-th input of the network gateway. $x_i(t)$ has the form of a sequence of intervals of the presence and absence of the i-th of the external factor affecting the reliability of the IN. From physical sense of the functions $x_i(t)$, that it determined in any time interval – $t(-\infty<t<\infty)$, and on any final subinterval of this interval $x_i(t)$ changes finite number of times. We assume that the value of the function

$x_i(t)$ at the time of the change $t=a$ is the same as its value at $t>a$. Then impact on inputs gateways network $x_1(t),....,x_n(t)$ are switching processes.

Reliability situation of communication channels, pass traffic various types of information in batch form defines the vector $B(t)$:

$$B(T) = [b_1(t), \dots, b_l(t)],$$

where $b_i(t)$ is a function of time, specifying the change reliability status of the i-th of the communication channel in the form of a sequence of intervals presence and absence of the operation of the channel. Similar to the previous processes of change reliability state communication channels $b_1(t),...,b_l(t)$ are switching processes. Call them reliability processes (RP) in communication channels.

On the transport level vector-function:

$$A(T)= [a_1(t), \dots, a_N(t)],$$

given the change of the RS routers and switches transport layer network , $a_i(t)$is a function of time, specifying the evolution of the reliability state of the i-th block in the form of a sequence of intervals presence and absence of capacity of work routers and switches. Similarly, previous to this, the processes of change of the reliability state routers and switches $a_1(t),...,a_N(t)$ – switching processes. Call them reliability processes (RP) in routers and switches.

At the level of the network control vector-function:

$$Y(T) = [y_1(t), \dots, y_r(t],$$

describes the change of the reliability state of the Softswitch of network, that is, change the performance of the network in relation to its functions. Here $y_i(t)$is the process of specifying the change of the capacity of work of the i-th input, that is, change the functionality of network in relation to its i-th functions. As above, install liven that the processes of change of the reliability state inputs level network management $y_1(t),..,y_r(t)$ – switching processes. Call them RP (reliability processes) in Softswitch on inputs level of management of the network.

Level of service is allocated in a separate component of network architecture. It occupies the upper plane of the considered model. Therefore, the level of management services vector-function:

$$V(T)=[v_1(t),\dots,v_m(t)]$$

describes the change of the reliability state outputs of the network, that is, change the level of quality of providing various multimedia services to users with a certain quality of service (QoS). Here $v_i(t)$ is the process of specifying the change of the reliability state of the i-th output, that is, the evolution of the capacity of work network in relation to its i-th functions. $v_i(t)$ has the form of a sequence of intervals run and fails to provide the services.

Thus, the reliability of the situation in the IN arbitrary moment of time t can be fully described in four vectors:

$$Z = (X, B, A, Y, V),$$

where X is the reliability state (RS) inputs (level gateways access); B – reliability state of communication channels; A – reliability state of blocks (routers and switches transport layer); Y – reliability state inputs (Softswitch), V – reliability state of outputs the NGN networks in the moment t (level of management services).

This description-static related to a selected moment of time. Actually, all four vectors depend on the time and reliability change of IN can be described vector function:

$$Z(T)=[X(T),B(T),A(T),Y(T),V(T)].$$

This description is dynamic, it inclusion the necessary interval of time of functioning of the information and communication network as a whole.

These group processes dependent. Indeed, the implementation of infocommunications network of its functions provide different types of information in a package are defined reliability processes (RP) in blocks network each level and input influences on the network. From physical considerations is that the implementation of the network of any of the i-th functions in any moment of time t depends only on the values of the NP in blocks and values of input actions at the same time t and previous times (and, possibly, from execution of a network of its functions in earlier times).

Thus,

$$\left.\begin{array}{l} v_1(t)=G_1[x_1(t),..,x_n(t);b_1(t),....,b_l(t),a_1(t),..,a_N(t),y_1(t),....,y_r(t)] \\ \text{.......... ....} \\ v_m(t)=G_r[x_1(t),...,x_n(t);b_1(t),....,b_l(t),a_1(t),..,a_N(t),y_1(t),...,y_r(t)] \end{array}\right\} \quad (1)$$

where $G_i(i=1,...,m)$ – own reliability operators (RO) of IN (infocommunication network).

Combination of the own reliability operators (RO) of IN: $G=(G_1,....,G_m)$ is the most complete, reliability characteristic. Knowing this feature, you can equations (1) to calculate reliability processes $v_1(t),...,v_m(t)$ at the outputs of the network at any given inputs $x_1(t),...,x_n(t),$ reliability processes $[b_1(t),...,b_l(t)]$ – communication channels, reliability processes $a_1(t),...,a_N(t)$ – routers and switches transport network and $y_1(t),...,y_r(t)$ on r inputs of the Softswitch of the network.

Received reliability processes $v_1(t),...,v_m(t)$ fully characterize the reliability of the results of the work of the IN. It is possible to calculate any indexes of reliability (IR) of the research network. The choice of that or another index of reliability of infocommunication network depends on reliability modes of operation – without recovery or restoration of failed units (network element). For infocommunication network without the restoration of the main index of reliability is the time T prior to the failure, defined as the time interval from the moment of the beginning of operation of the network t_0 to her first refusal (Skvorsov, 2011).

Other indexes of reliability networks can serve the function of availability $K_\Gamma(t)$, defined as to:

$$K_\Gamma(t) = \begin{cases} 1, \text{ if the network at the moment } t \text{ buildable;} \\ 0, \text{ if the network at the moment } t \text{ unworkable} \end{cases} \quad (2)$$

and the reliability function $P(t)$:

$$P(t) = \begin{cases} 1, \text{ in the absence of failures on the interval } [t_0, t]; \\ 0, \text{ otherwise.} \end{cases} \quad (3)$$

Functions $K_\Gamma(t)$,$P(t)$ of non-restorable network are switching processes of the same type:

$$K_\Gamma(t) = P(t), \quad (4)$$

so indexes of reliability $K_\Gamma(t),P(t)$ are dependent.

For networks with the restoration, the main indexes of reliability serve the function of availability $K_\Gamma(t)$ (as in contrast to (4) switching process with several modifications) and resource V, defined as the time interval from the moment of the beginning of operation of the network t_0 until its final (non-restorable) for the rejection.

Used and the reliability function $P(t),$ which has the type (3), as well as the availability K_Γ – percentage of time during which IN buildable. It is equal to:

$$K_\Gamma = \left[\int_{t_0}^{t_0+V} K_\Gamma(t)dt \right] / V, \quad (5)$$

that is, the value of the function of availability $K_\Gamma(t)$ on the interval (t_0, t_0+V).

Often reliability of restored NGN characterize time T_i between failure (defined as the time interval from the moment of the next of the i-th restore the network until next after his refusal, and the time of the i-th recovery T_{Bi}.

As seen from (2) and (5), the availability $K_\Gamma(t)$ is the primary index of reliability of network, through which expressed its other indexes of reliability. Note that when the $T_i=T$, $T_{Bi}=T_B$:

$$K_\Gamma = T/T+T_B \quad (6)$$

Calculation indexes of reliability by ratio (1) requires the knowledge of the criterion of failure of the NGN network. This criterion depends on the operating mode. If according to the conditions of work IN (infocommunication network) should run simultaneously to all m of its functions, the criteria of a network failure is the failure of at least one of these functions.

If IN must perform at least one of the possible functions, the criterion of failure – failure m functions. If the network should perform no less than p(1<p< m) functions, the criterion of a network failure – the failure of not less than m - p of any functions.

The more complicated the criteria of a network failure; for example, consider the following valuation of the various functions of the network. Knowledge of the criterion of a network failure allows it by the indexes of reliability $K_Г(t)$ and $P(t)$ through reliability processes on the outputs of the network $v_1(t),...,v_m(t)$:

$$K_Г(t) = v_{ЭКВ}(t) \quad (7)$$

Here $v_{ЭКВ}(t)$ is equivalent to the reliability processes in NGN network received by unification of all reliability processes on the outputs of the network:

$$P(t) = \begin{cases} 1, & \text{if } v_{ЭКВ}(\tau) = 1 \quad \text{for } 0 \le \tau \le t; \\ 0, & \text{in other case.} \end{cases}$$

Thus, calculation of various indexes of reliability analyzed IN is reduced to one more general problem of the definition of reliability processes on the outputs of the network. The introduced above operator dependence (1) reliability processes on the outputs of the network are a function of IN from reliability processes on its inputs and in blocks and ask reliability model of the network.

This model has two important features:

1) functionality of research IN determined not only by the workable of its units, but also impact on its inputs;
2) functionality of the infocommunication network in any current moment of time may depend on the workable units and input influences not only this, but previous times.

Conclusions

Thus, for research of reliability indexes of infocommunication networks it can be presented in the form of subsystems, which are separate, levels that perform specific functions and tasks in packet regime with the specified quality of service. The research of reliability indexes of infocommunication networks appropriate employed on the basis of system approach when accounting for reliability states of each level. In further research will be calculated indexes of reliability for each level separately and for infocommunication networks in general.

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