THE CONTROL OF DEVELOPING A STRUCTURE OF A CATASTROPHE-RESISTANT SYSTEM OF INFORMATION PROCESSING AND CONTROL

I.V. Kovalev, P.V. Zelenkov, M. Yu. Tsarev
Siberian State Aerospace University named after Academician M.F. Reshetnev
31 "KrasnoyarskiyRabochiy" prospect, Krasnoyarsk, 660014, Russia.

E-mail:zelenkov@sibsau.ru

Abstract. The problem of the planning and control of developing a cluster structure of a catastrophe-resistant system of information processing and control is solved. The criterion for optimality for the plan of developing the structure of a catastrophe-resistant system of information processing and control is formalized using the rate of change in demands from system units and expenses for developing the cluster network as a whole.

The growing complexity of the systems of information processing and control which is connected to growth in size and complexity in organizational-technological and industrial routines provides a set of tasks which are connected to scientifically-approved developing and perfecting of their structure. The systems which are critical to reliability should have an adequate level of fault-tolerance using a predefined budget. Fault-tolerance usually means the amount of failed elements at the same time which would lead to the failure of the system as a whole. The more elements that are required for the failure of a system, the more fault-tolerant this system is. Fault-tolerance increases the reliability of a whole system which is built from insufficiently reliable components. The fault-tolerance requirements are defined using the difference between the required level of reliability and the real reliability of the available components. Reliability is the percentage of time while the system is in working condition. The higher this variable is the less this system is in non-functional condition. The systems which are critical to reliability should achieve 99.9% reliability. The common requirement today is "five nines" which is equal to 5 minutes of offline time per year. The same requirements should be applied to network hardware, connection and electrical availability. It is obvious that the reliability of the servers should be higher than the reliability of the work stations and mobile devices.

The simple duplication of the structural components of the system is not an effective solution to the problem of the provision of the fault-tolerance of a system. There is a set of cluster solutions, but the task of the effective control of the development of a system structure is not solved. Also, the growing complexity of the system provides extended requirements in effectiveness and quality of decisions on different stages of its development.

The problem of an increase in the resistance of cluster solutions for structure-complex systems to faults in a working process using the method of controlling their development is considered in this article. The formalization of the task of planning of a queue and a set of stages for the creation of complex and cluster systems of information processing and control as well as the optimization model which provide the ability to find the moments of the

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beginning and ending of developing of interconnected objects of cluster structures, using the distribution of resources between them on the planning stage are considered. The new approach can be used to solve tasks in the investment planning process for creating full-scale catastrophe resistant systems of information transmission and processing which are used for modern satellite technology.

The main topic of this article is a solution of the problem of the increase in hardware reliability of systems of information processing and control using the approach of building clusters. The cluster solutions are considered from the point of view of their catastrophe resistant ability. The catastrophe-resistant ability is defined as the ability of applications and data to recover in a minimal time period after a catastrophe. The term catastrophe means not only fire, flooding or earthquake but also unpredicted faults, eradication of data or damage to the processing centre (for example: as a result of accidents during repair works or sabotage). The development of a structure of the catastrophe-resistant system of information processing and control expects building defense from unplanned downtime periods during and after a catastrophe in the geographically distributed cluster nodes, which provides ability for a system to continue work with faults in single nodes.

As ageneral rule, thesupport and development of catastrophe-resistant configuration is not limited by deploying only hardware-software solutions (cluster organization, software components of performance control installation, resources, infrastructure and so on), but should also include the specialized services provided by the manufacturer, another company or customer itself (operability monitoring, backup and so on).

The development control according to [4,8] is defined as the process of finding the moments where different types of clusters can be used and the process of choosing a structure of a cluster network in every period of the planning and power streams between clusters of different levels of hierarchy (according to a predefined category of its catastrophe-resistant ability). Simultaneously, the dynamics of the changeinthe needs of the users of every structural component (AP server)in the information-technological works and expenses for its development is considered.

The hardware-software solutions for the complex structures of that type of system which provide catastrophe-resistant ability, match to the following types of a cluster.

The local cluster is a cluster, where all nodes are located in a single centre. This does not provide catastrophe-resistant ability, though most clusters of high readiness are of this basic type.

The campus cluster is used as the alternative method of placement for the processing and storage data nodes which are scattered across the territory of a company. A fault in a single building does not lead to the downtime of the whole system. The distances between the nodes are limited by the chosen data replication technology. The following statements are common for the structural organization of clusters of that type:

1. extra disks with replication data providers;
2. extra network wires which are used in the different routes;
3. alternative power sources for every node(electricity can be provided by different operators and that fact defends the cluster from power failures) .

The metro cluster is a cluster of the city or city district type. It includes the duplicated nodes which are located in different parts of the city or the suburbs.

The placement of the nodes using the long distances between the duplicated nodes greatly reduces the chance of the simultaneous failure of both nodes. The structure of the metro cluster is similar to the structure of the campus cluster with one significant difference in the distances between the nodes which are much longer in the metro cluster. Special permissions for the placement of network and replication data cables are required for building a metro cluster, and can cause difficulties for the deployment of a cluster.

The use of the metro cluster assumes the existence of synchronization services. Usually an arbitrator which contains an additional node which consists of a dedicated server and performs connection and synchronization work for other nodes is used to solve the latter task. The arbitrators are the fully functional subsystems which are subparts of a cluster but not connected to the storage system.

The metro cluster supports configurations with one or two arbitrators. However a configuration with two arbitrators is preferable, because they provide a higher level of readiness. The main difference between campus and metro clusters is the technology of data replication.

The continental cluster is a set of duplicated subclusters which are placed in the distantly connected locations and do not use local networks for interconnection between them. Every subcluster which is included in the structure of a continental cluster is self-sustained. That is why, an arbitrator is unnecessary here. Global networks based on the TCP/IP protocol are used for interconnection between the subclusters, as for data replication, high speed dedicated lines such as T1/E1 or T3/E3, could be necessary.

Therefore the effective functioning of a catastrophe-resistant system is reached by placing its components far away from each other. It allows the ability to connect the system to different power facilities, excluding the probability of a power failure and providing the continuous functioning of the system under the condition of not only the failure of a single node of a subcluster but also the failure of a whole subcluster. Simultaneously the role of connection canals for the interconnection between clusters is growing. If risk of damaging wires within a building is low, then it is possible to use cheap solutions for the interconnection, but it is an inappropriate solution for a metro cluster, because in this case, a connection canal is a very important element of the system architecture. The planning of placement of the main and reserve connection canals, using different routes, is required for building catastrophe-resistant clusters.

The stage of the selection of a type of system which meets the main requirements for the achievement of catastrophe-resistant ability for the system as a whole is very important during the forming of the optimal plan for the development of the cluster structure of the catastrophe-resistant system of data processing and control process. This stage consists of the following steps:

- the geographical placement of nodes;
- data replication;
- several independent power sources;
- highly reliable network infrastructure.

Considering the scenarios of the functioning of the clusters which meet different levels of reliability and catastrophe-resistance, it is important to point out the dynamic characteristic which is calculated every time when a cluster node fails. This characteristic of cluster integrity is named the "cluster-quorum". For our task the cluster-quorum is defined as the minimal integrity of a cluster wherein it is still in working condition. This is a per cent characteristic which indicates the minimal amount of parts of the cluster which can process all of the tasks. The value 40% of the cluster-quorum means that under condition of the failure of

60% of the hardware, the cluster can function without any errors using 40% working hardware. Therefore, the ideal cluster-quorum should aim for the zero value.

The set of the cluster node coefficients should be chosen by experts in order to calculate the cluster-quorum value. After that, the per cent equivalent of importance value for every node is calculated according to the corresponding coefficient. Next, the cluster integrity violation variants with the corresponding operability estimation are formed. The minimal operable value of integrity is used as the cluster-quorum.

The Analysis of the functioning of cluster systems shows that a cluster is able to reconfigure under the condition where the amount of working nodes is more than the amount of faulty ones only. Therefore, the "cluster-quorum" value calculation is enough to make decisions during the process of the consequence estimation of different scenarios of failures.

The considered architectural solutions for the development of the cluster structure for the data processing and control system include a set of nodes which are located in the data processing centers. Furthermore the nodes include a set of the structural items which work in the same information field with equal rights (applications, hdd arrays, arbitrators and so on) and are connected to each other by using communication channels which are provided by the high readiness networks or by networks with uninterrupted access for the hdd arrays. Each data processing center is characterized by the needs in technical resources of their nodes and the catastrophe-resistant category of the cluster on every stage of the planning of the development of a data processing and control system structure.

The catastrophe-resistant category of the data processing center is characterized by the value of the cluster-quorum and the set of hardware and software which are used in the nodes. Therefore, the process of the cluster structure of the system development which provides sequential increase in the catastrophe-resistant ability level is shown as a set of lines on a graph, where its node set is a set of possible catastrophe-resistant categories for every data processing center at every defined planning period and its set of edges is all possible transitions from one category to another.

The planning and control of the system cluster structure development task is the process of finding of the optimal plan for the development of the cluster which should define the start time of data processing centers as well as the structure of the cluster network at every stage of the planning process. It is also important to use the dynamics of the change in the needs of the system nodes and the expenses for the development of the cluster network as a whole.

Depending on the task definition, the criterion of optimality for a plan for the development of the catastrophe-resistant data processing and control system structure is formalized. In many cases it is important to include coefficients which consider the importance of information-technical resources which are required by the i-th item. Simultaneously, the common limitations on the expenses for the creation of the hardware and software for the whole catastrophe-resistant infrastructure are used. The limitations for the degree of the satisfaction of the users' needs in information-technical services at the different periods of the planning process are also important.

The considered model provides ability to do the optimization and analysis of the variants of the development of the cluster structure for the catastrophe-resistant data processing and control system processes.

Let us consider an optimization task, which is needed to be solved during the planning of the development of the structure of an catastrophe-resistant, cluster system. So, there is a system which consist of a set of I clusters. $i = \overline{1, I}$ is the number of a cluster. Every cluster is characterized by: catastrophe-resistant category ($k=\overline{1,K}$), district coefficient μ_i and need in cluster-quorum Q_{it} at the time t. On the time interval T at every planning period t $(t=\overline{1,T})$ the amount of resources R_t for the development of the catastrophe-resistant cluster system is given. The district coefficient μ_i takes into account the increase in the expenses for building a cluster in the special regions such as northen regions, seismically active regions and so on.

Every category k has matching minimal values of Q_k and R_k .

Let us consider the following variables to formalize the task.

$x_{ikt}=1$, if the i-th cluster has the k-th category at the t-th planning period,

$x_{ikt}=0$, otherwise.

Let us define $q_{ikt}=Q_{it}-Q_k$ as the difference between the required minimal integrity of the i-th cluster at the t-th period and the cluster-quorum of k-th category.

Considering

$$\tilde{q}_{ikt}=\begin{cases}-q_{ikt}, if\ q_{ikt}<0\\ 0, if\ q_{ikt}\geq 0\end{cases} \quad (1)$$

$$\bar{q}_{ikt}=\begin{cases}q_{ikt}, if\ q_{ikt}>0\\ 0, if\ q_{ikt}\leq 0\end{cases} \quad (2)$$

the expression which characterizes the degree of the advantage of needs for integrity to the integrity violation of the cluster structure can be presented as the following:

$$\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\tilde{q}_{ikt}\cdot x_{ikt} \quad (3)$$

$$\sum_{k=1}^{K}x_{ikt}=1, i=\overline{1,I},\ t=\overline{1,T}\ , \quad (4)$$

The condition for choosing the category from the set of acceptable values for every cluster formalizes as the following:

where I is the amount of clusters.

The condition which limits the set of possible categories for the i-th cluster at every t-th period can be written as:

$$\sum_{k=1}^{K}k\cdot x_{ikt}\leq K_{it}^{*}, i=\overline{1,I},\quad t=\overline{1,T}, \quad (5)$$

where $K_{it}^{*}=\min_{Q_k\geq Q_{it}} k$ is the minimal category which has the cluster-quorum which fully satisfies the demands of the i-th cluster at the t-th planning period ($k=\overline{1,K}$).

Using the district coefficient μ_i , the limitation on expenses at the time period t formalizes as the following:

$$\sum_{i=1}^{I}\mu_i\sum_{k=1}^{K}x_{ikt}\cdot\left(R_k\cdot x_{ikt}-R_k\cdot x_{ik(t-1)}\right)\leq R_t \quad (6)$$

In our case, an important condition is the satisfaction of the user's queries, thus the minimal value of the expression (3) is used as the criterion for optimality of the development plan:

$$\min \sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{k=1}^{K} \tilde{q}_{ikt} \cdot x_{ikt} \qquad (7)$$

Therefore, the plan which provides the minimal reliability deficit (expression (7) on the whole time interval which is provided for the development of the system, using the limitations (4)-(6)) will be optimal.

The analysis of reliability and the development control of the cluster structures software is created and presented In the article[8]. The successful approbation of this software shows that it can be used to solve the considered tasks for the creation and development of data processing and control systems which are used in many areas.

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