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Resources Redistribution Method of University e-learning on the Hyperconvergent platform

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***Abstract*— In this article a method of constructing a graph model of university e-learning functioning process, deployed on a hyperconvergent platform, proposed. The method is based on problems and objectives of the system structure analysis. The created graph considers available e-learning resources.**

Keywords — e-learning, hierarchical structure, widgets

I. Introduction

Current trends in IT development necessitate the complex university systems of e-learning support transfer on the hyperconvergent platform.

E-learning on the hyperconvergent platform can be considered as complex organizational hierarchical system. In scientific development much attention is paid to research of properties of hierarchical systems, processes of their functioning [1, 2]. It is known that decision-making process in different complex organizational hierarchical systems has its own features. These features should be considered in case of creation of the appropriate systems. In this connection, the problem arises of determining the corresponding singularities. The most effective way to solve it is the functioning processes modelling [3–5]. The organizational system is considered as some mathematical object. Its research is carried out on the basis of studying the properties of this object.

However, the resources of an e-learning system are limited. According to its successful implementation there is a need to ensure its maximum usage at all levels of the system. Consequently, as an essential element of entire system, there should be a rapid reallocation of resources subsystem.

The subject of the study is the electronic educational resources of university e-learning.

The purpose of the article is to develop a method of a rapid resources redeployment of e-learning on a hyperconvergent platform.

II. Analysis of Existing Approaches

In the sources [1, 2] much attention is paid to the consideration of systems with hierarchical structure.

In [3] an approach to the description of the modeled system is proposed. Here, the organizational system is perceived as a set of interacting elements. The nature of this interaction depends on the objectives or tasks facing the system. It is assumed that the set of elements is fixed. The description level of such systems is determined by the selected detail level of the considered processes.

In [4] the possibility of interaction of the elements of the system with each other is considered. Elements' information channels of communication are analyzed. The type of the channel is identified with the type of information. The general list of information channels is determined by the level of the system description. The structure of the system is characterized by the indication of the functioning communication channels between its elements. Each problem is considered as a system transformation operator. The process of solving the problem in the system is manifested by adjusting its structure in accordance to the task.

In [5] it was shown that the structure of the system can be interpreted as the state of the system at some time moment. In hierarchical systems, all states are hierarchies. In each hierarchical system, a set of structures that are hierarchies can be specified. The definition of a complete hierarchical system is proposed.

In [6–8] the main problems that arise in modeling process of complex organizational hierarchical system are shown:

– identification of systems and specification of model components; selecting a method for determining a parameter model;

– classification of organizational systems;

– the choice of the subsystem and its communication operations;

– the study of structures within the framework of one system under study.

III. Model of E-learning

We associate with the graph G_X, the graph which is isomorphic to it:

$$G_C(\overline{C}, H),$$

where:

$\overline{C}$ – set of system goal vertexes;

$H = \left\{h^{i}_{j\nu}\right\}$ – set of arcs of a graph G_C.

Each arc defines the relationship between the conditions for achieving the goals.

In the process of reaching the main objective of the system C_0, external perturbations arise. They have mostly situational, non-stochastic character. For governing bodies of $(m-1)$-th rank $\left\{X^{\nu_{m-1}}\right\}$, $1 \le \nu_{m-1} \le \ell_{m'}$, there is a set of the objects and tasks on elimination of deviations. This fact leads to non-fulfillment of the appropriate objectives $\left\{C^{\nu_{m-1}}\right\}$.

A set of the aims and tasks facing governing bodies $\left\{X^{\nu_{m-1}}\right\}$ is considered next. This set has been presented in the form of a set of graphs $G^{m-1}_{C_0} = \left\{G^{\nu_{m-1}}_{C_0}\right\}$ of system objectives and tasks:

$$G^{\nu_{m-1}}_{C_0} = \left(\overline{C}^{\nu_{m-1}}_0, h\right), \tag{2}$$

where:

$\overline{C}^{\nu_{m-1}}_0 = \left(C^{\nu_{m-1,0}}_0, \overline{C}^{\nu_{m-1,1}}_0, ..., \overline{C}^{\nu_{m-1,n-1}}_0\right)$ – a tuple, consisting of a number of operative management objectives for different ranks;

$C^{\nu_{m-1,0}}_0$ – the main objective of operative management of ν-th governing body of $(m-1)$-th ranks;

$\overline{C}^{\nu_{m-1,f}}_0 = \left(C^{\nu_{m-1,f,1}}_0, ..., C^{\nu_{m-1,f,\ell_f}}_0\right)$; $0 \le f \le n-1$;

f – the rank identifier in the graph $G^{\nu_{m-1}}_{C_0}$;

l_f – number of objectives of f-th ranks;

$h = \left\{h^{f}_{jg}\right\}$, $0 \le f \le n-2$; $1 \le j \le l_f$; $1 \le g \le l_f + 1$ – set of arcs of a graph.

Peaks in the graph $G^{\nu_{m-1}}_{C_0}$ are connected by edges $h^{f^{\nu_{m-1}} Z^{\alpha_{m-1}}}_{j\Theta}$, where $0 \le f \le n(\nu)-1$; $0 \le Z \le n(\alpha)-1$; $1 \le j \le l_f$; $1 \le \Theta \le l_Z$, with one or several peaks in the graph $G^{\alpha_{m-1}}_{C_0}$; $\alpha \ne \nu$; $0 \le \alpha, \nu \le \ell_Z$ (fig. 1). The next step is to put in correspondence of each connection for $h^{f^{\nu_{m-1}} Z^{\alpha_{m-1}}}_{j\Theta}$ the set of tasks until reaching the highest rank of governing body (GB) of structure G_X. These are tasks on coordination of GB $X^{\nu_{m-1}}$ and $X^{\alpha_{m-1}}$ in case of the managerial decision making by them.

In this way, a graph of coordinating objectives and tasks can be constructed (fig. 1):

$$G_{CK} = (\overline{C}_K, S_K), \tag{3}$$

where:

$\overline{C}_K = (\overline{C}^0_K, \overline{C}^1_K, ..., \overline{C}^{m-2}_K)$ – the vector consisting of a set of the coordinating objectives of GB of different ranks;

$\overline{C}^0_K = (C^0_{K1}, C^0_{K2}, ..., C^0_{K\ell_0})$ – a set of the coordinating aims of governing body X_0 in graph G_X;

$\overline{C}^{ij}_K = (C^{ij}_{K1}, C^{ij}_{K2}, ..., C^{ij}_{K\ell_t})$, $1 \le j \le l_i$; $0 \le i \le m-2$; $1 \le t \le lt$ – the set l_t of the coordinating control aims X^i_j;

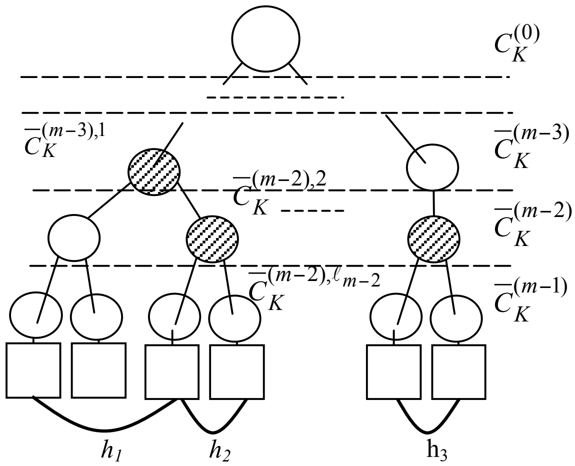


Figure 1. Graph of the coordinating objectives and tasks

$$S_K = S^T_K \cup S^{TA}_K, \; S^T_K \cap S^{TA}_K = \varnothing, \tag{4}$$

where:

$S^T_K = \left\{S^{Tt_{ij}}_{k\omega_{\tau\gamma}\nu}\right\}$, $1 \le t, \; \omega \le l_t$; $0 \le i, \; \tau \le m-2$; $1 \le j \le l_i$; $1 \le \gamma \le l_\tau$; $1 \le \nu \le l_m - 1$ – set of the nonoriented relations of the τ-th and ω-th coordinating objectives of j-th governing body of i-th rank and γ-th governing body of τ-th rank in case of the operative decision making tasks of ν-th governing body with $(m-1)$-th rank management;

$S^{TA}_K = \left\{S^{TAt_{ij}}_{k\omega_{\tau\gamma}\nu}\right\}$ – set of the oriented (transitively-antisymmetric) relations between the appropriate coordinating objectives.

Creation of the coordinating objective C^{ij}_{Kt} of interrelation $h^{f^{\nu_{m-1}} Z^{\alpha_{m-1}}}_{j\Theta}$ in the graph $G^{\nu_{m-1}}_{C_0}$ is carried out as follows: in the graph G_X the governing body is determined on the smallest value of a rank i, with which organs α and ν with the rank (m – 1) are transitively connected by the relations $R = \left\{r^i_{j\nu}\right\}$.

Let $\overline{C}_0^{\nu_{m-1}}$ – quantity of the resources provided for the operative management objectives accomplishment to the ν-th governing body of $(m-1)$-th rank. GB X_j^i is transitively connected with ν relations $R = \left\{ r_{j\nu}^i \right\}$.

These relations define tasks $\overline{C}_{\Pi}$ on redistribution of resources between governing bodies with indexes ν and α $(1 \le \nu, \alpha \le \ell_{m-1}, \nu \ne \alpha)$ of $(m-1)$-th rank .

The graph of the purposes and tasks of operational redistribution of resources has been constructed

$$G_{C\Pi} = (\overline{C}_{\Pi}, S_{\Pi}), \tag{5}$$

where:

$\overline{C}_{\Pi} = (\overline{C}_{\Pi}^0, \overline{C}_{\Pi}^1, ..., \overline{C}_{\Pi}^{m-2})$ – the tuple, consisting of a set of purposes on resources redistribution process;

$\overline{C}_{\Pi}^0 = (C_{\Pi 1}^0, C_{\Pi 2}^1, ..., C_{\Pi \ell_t}^{m-2})$, $1 \le t \le l_t$ – the set of objectives related to redistribution of the resources facing governing body X^0.

Similarly, for governing bodies X_j^i:

$$\overline{C}_{\Pi}^{ij} = (C_{\Pi 1}^{ij}, C_{\Pi 2}^{ij}, ..., C_{\Pi \ell_t}^{ij});$$

$$S_{\Pi} = S_{\Pi}^T \cup S_{\Pi}^{TA},$$

$$S_{\Pi}^T \cap S_{\Pi}^{TA} = \varnothing, \tag{6}$$

where:

$S_{\Pi}^T = \left\{ S_{\Pi \omega_{\tau\gamma} \nu}^{Tt_{ij}} \right\}$, $1 \le t,\ \omega \le l_t$; $0 \le i,\ \tau \le m-2$; $1 \le j \le l_i$; $1 \le \gamma \le l_\tau$; $1 \le \nu \le l_m - 1$ the nonoriented relations of t-th and ω-th objectives of redistribution resources of j-th GB with i-th rank and γ-th GB with τ-th rank; they provide the operative management of GB objectives solving $\nu_m - 1$;

$S_{\Pi}^{TA} = \left\{ S_{\Pi \omega_{\tau\gamma} \nu}^{TA_{ij}} \right\}$ – set of the relations between the appropriate objectives on redistribution of resources.

GB with indexes ν and α $(1 \le \nu_{m-1}, \alpha \le \ell_{m-1})$ of $(m-1)$-th rank, which have isomorphic graphs $G_{C_0}^{\nu_{m-1}}$ and $G_{C_0}^{\alpha_{m-1}}$ objectives and tasks of operative management have been named as similar type units.

On a set of GB $\overline{X}^{m-1} = \left\{ X^{\nu_{m-1}} \right\}$, $1 \le \nu \le \ell_{m-1}$, a partition $\left\{ U_1, U_2, ..., U_{\ell_y} \right\}$ of a set $\overline{X}^{m-1}$ will be set on types ($y = \overline{1, \ell_y}$ – set of types of GB of $(m - 1)$-th rank).

Thus, for setting a set of the objectives and tasks of operative management on a G_X structure it is enough to define:

– the graphs of objects and tasks of operative management of each types of GB of $(m-1)$-th rank;

– set of edges $h = \left\{ h_{j\Theta}^{f^{\nu_{m-1}} z^{\alpha_{m-1}}} \right\}$, which defines dependence of operational management objectives of organs accomplishment $X^{\alpha_{m-1}}$ and $X^{\nu_{m-1}}$;

– set of pointers $d = \left\{ d_{fj}^{\nu_{m-1} \alpha_{m-1}} \right\}$, which establish possible relations on resources redistribution of:

– displaying:

$$F_{\Pi} : d \to \overline{C}_{\Pi};\ F_K : h \to \overline{C}_K. \tag{7}$$

The structure W of objectives and tasks of operative management is being set on the graph G_X by the tuple of six elements

$$M = \left\langle G_X, G_{C_0}^{m-1}, G_{CK}, G_{C\Pi}, F_{\Pi}, F_K \right\rangle. \tag{8}$$

Thus, it has the form of a union of substructures

$$W = \bigcup_{\nu=1}^{\ell_{m-1}} W_\nu .$$

IV. Method of resource allocation

The next step is a decomposition of each graph from the set $G_{C_0}^{m-1}$. To this end, a family of embedded partitions

$$K = \left\langle K^1, ..., K^{n-2} \right\rangle \tag{9}$$

on graphs $\left\{ G_{C_0}^{\nu_{m-1}} \right\}$:

$$K^f = \left\langle K_1^f, ..., K_{\ell'_f}^f \right\rangle, \tag{10}$$

and

$$\bigcup_{j=1}^{\ell'_f} K_j^f = G_{C_0}^{\nu_{m-1}},\ K_j^f \cap K_\rho^f = \varnothing,\ j \ne \rho,$$

$$1 \le f \le n-2,\ 1 \le \ell'_f \le \ell_f$$

must be constructed.

Any set member K_j^f is a combination of several subgraphs $K_1^{f+1}, ..., K_{\ell'_{f+1}}^{f+1}$ of the level $(f+1)$.

Partition is managed as follows. In the graph $G_{C_{0,f}}^{\nu_{m-1}}$ ($C_{0,f}^{\nu_{m-1,j}}$ – is a root $G_{C_{0,f}}^{\nu_{m-1}}$) subgraphs are being selected with peaks $\left\{ C_{0,f+1}^{\nu_{m-1}} \right\}$. They are connected by relationships h_{jg}^f with $C_{0,f}^{\nu_{m-1}}$.

Thus, the partition $K = \left\langle K^1,...,K^{n-2} \right\rangle$ defines a set of independent for relations $\left\{ h_{jg}^f \right\}$ subgraphs on the graph $G_{C_0}^{\nu_{m-1}}$.

It can be represented as

$$G_{C_0}^{\nu_{m-1}} = \bigcup_{\beta^\nu=1}^{U} G_{C_0,\beta^\nu}^{\nu_{m-1}}. \tag{11}$$

A set of external influences has been specified as

$$\bar{\alpha} : \left\{ G_{C_0}^{\nu_{m-1}} \right\} \to \left\{ G_{C_0}^{\nu_{m-1}*} \right\}, \tag{12}$$

where:

$\left\{ G_{C_0}^{\nu_{m-1}*} \right\}$ – set of the subgraphs, objectives and tasks of operational management exposed to external influence.

Let

$$\bar{\beta} : \left\{ G_{C_0}^{\nu_{m-1}*} \right\} \xrightarrow{K} \left\{ G_{C_0,\beta^\nu}^{\nu_{m-1}*} \right\} - \tag{13}$$

representation of a set $\left\{ G_{C_0}^{\nu_{m-1}*} \right\}$ in a set of the subgraphs determined by partition *K*.

The process of determining a set of subgraphs of the objects of operational management will have the form:

$$\left\{ G_{C_0}^{\nu_{m-1}**} \right\} \subset \bigcup_{\beta^\nu=1}^{U} G_{C_0,\beta^\nu}^{\nu_{m-1}*} \cup$$

$$\cup \left(\bigcup_{\beta^\nu=1}^{U} G_{C_0,\beta^\nu}^{\nu_{m-1}} \cap \left\{ \left\{ G_{C_0,\beta^1}^{1,m-1} \right\} \times ... \times \left\{ G_{C_0\beta^\ell}^{\ell,m-1} \right\} \right\} \right). \tag{14}$$

Resource allocation structure $S_{pr\nu}$ will be presented in the form of a graph

$$S_{pr_\nu} = \begin{pmatrix} G_{C_0}^{\nu_{m-1}} = \left\{ G_{C_0K}^{\nu_{m-1}} \right\} \cup \\ \cup \left\{ G_{C_0B}^{\nu_{m-1}**} \right\} \cup \left\{ G_{C_0H}^{\nu_{m-1}**} \right\}, R^S \end{pmatrix}. \tag{15}$$

The peaks in S_{pr} – in the form of subgraphs $\left\{ G_{C_0B}^{\nu_{m-1}**} \right\}$, which are not provided with resources $\left\{ G_{C_0H}^{\nu_{m-1}**} \right\}$. To each peak of $\left\{ G_{C_0H}^{\nu_{m-1}**} \right\}$ the vector of required resources is defined:

$$e_B = \left(e_B^1, e_B^2, ...e_B^{\ell_B} \right) \tag{16}$$

R^S – a set of arcs from $\left\{ G_{C_0K}^{\nu_{m-1}} \right\}$, $\left\{ G_{C_0B}^{\nu_{m-1}**} \right\}$ into $\left\{ G_{C_0H}^{\nu_{m-1}**} \right\}$. They are defined by the elements of the set $\left\{ G_{C_0H}^{\nu_{m-1}**} \right\}$. Vector of resources is incidental to each arc:

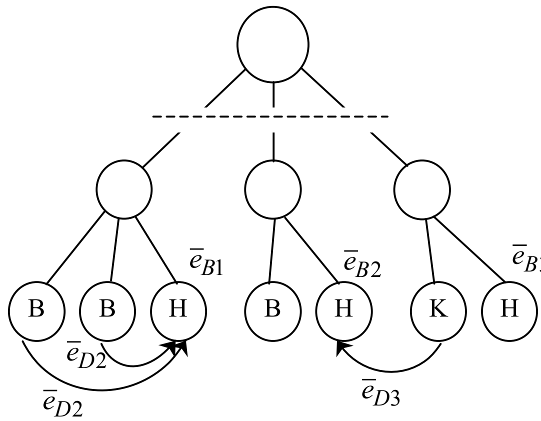
$$e_D = \left(e_D^1, e_D^2, ...e_D^{\ell_D} \right). \tag{17}$$

At the same time

$$\sum_{a \in \ell_a} e_{D_a} = e_{B_C} \text{ (fig. 2).} \tag{18}$$

Thus, on a set $\left\{ G_{C_0}^{\nu_{m-1}} \right\}$ it is possible to define a set of structures S_{pr}, by setting different R^S. As a result the set $\left\{ G_{C_0B}^{\nu_{m-1}**} \right\}$ will be received, including different subgraphs of operational management objectives, located before $X^{\nu_{m-1}}$.

Each of structures $\left\{ S_{pr}^{\nu_{m-2}} \right\}$ determines the distribution of resources between direct descendants of GB ν_{m-2}.



$\bar{e}_{B1} = \bar{e}_{D1} + \bar{e}_{D2}$ $\quad\bar{e}_{B2} = \bar{e}_{D3}$ $\quad\bar{e}_{B3} = 0$

Figure 2. Structure of resources redistribution (B, K, H – types of resources)

V. Analysis of results

For assessment of efficiency of resource allocation process the "validity" criterion is selected. Calculation of a probabilistic index for this criterion was implemented out by the formula [9]:

$$\eta = \max_\ell \eta_\ell = \max_\ell \left| x_\ell^{(0)} - x_\ell \right|, \ \ell = \overline{1,u}, \tag{19}$$

where inaccuracies $\eta_\ell = x_\ell^{(0)} - x_\ell$ are random variables, having the distribution law for ℓ-th parameter $f(x_\ell)$.

The validity of the decision while reviewing m of options is calculated as probability:

$$P = 1 - \prod_{\alpha=1}^{m} \left(1 - \frac{1}{m_0} \prod_{\ell_\gamma=1}^{u_\gamma - \mu_\gamma} \left[\int_{-\varepsilon_{\ell_\gamma}}^{\varepsilon_{\ell_\gamma}} f(x_{\ell_\gamma}) dx_{\ell_\gamma} \right] \right). \tag{20}$$

Diagrams of dependencies of the validity level for the decisions made regarding the resources allocation and the number of analyzed options are shown in fig. 3.

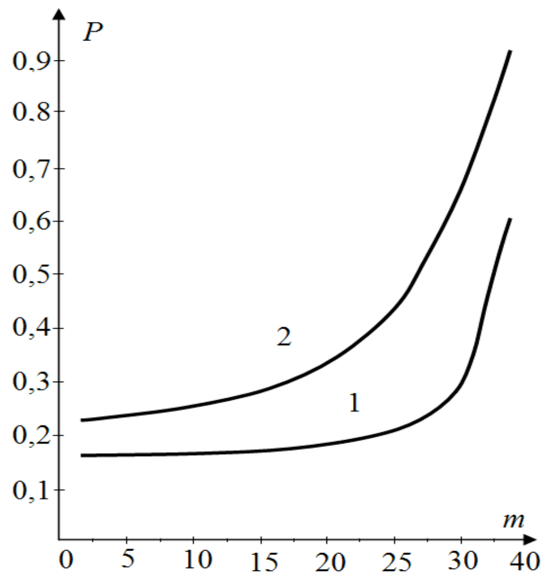


Figure 3. Dependence of the validity level of resources (P) allocation process and the number options analyzed (m):
1 – without taking into account the graph model;
2 – taking into account the graph model

VI. CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH

A method of constructing a graph model of the university e-learning functioning on a hyperconvergent platform is offered. E-learning is considered as difficult organizational hierarchical system. The method is based on the objectives and tasks of the system structure analysis. The created graph considers available e-learning resources. The distribution model of resources on the basis of this graph is offered. In further it is planned to develop a method of finding the optimal resources allocation.

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