CONCEPTS OF DYNAMIC CONTROL OVER DISTRIBUTED COMPUTER SYSTEMS FUNCTIONALITY

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To reach the effective organization of distributed computational processes it is important to provide the functionality at the level appropriate for guaranteed and successful execution of computational processes of the task being solved.

Solving the problem of distributed computer systems (DCS) functionality provision has become particularly acute in connection with following factors.

DCS has become a popular instrument; distributed computation nowadays is becoming a widely used instrument to solve different classes of practical tasks;

Conference participants,
National championship in scientific analytics

Multiplicity and variety designation of the tasks being solved have brought to the fact that both DCS functionality and information-computation processes fulfilled by DCS turned out to be diversiform, complex with multiple properties and characteristics.

Proceeding from the demand of practice there appeared the new classes of distributed computer systems created on the base of such technologies as virtual, mobile, GRID, cloud and meta-computing.

All that require both perfection of existing and creation of new classes of technologies and means providing high functionality of DCS, securing guaranteed and effective execution of computation and information processes of applied tasks being solved by DCS.

Our work analyses peculiarities of DCS functionality provision task and the ways of its solution proceeding from the system position [1-3].

Approach consistency lies in the fact that there established various tasks which can occur within the operation of DCS, there after by means of analysis and/or research there defined their characteristics.

Proceeding from peculiarities of those tasks there is fulfilled the statement and setup of the problem of DCS functionality dynamic control. Further the formulated task is studied and its peculiarities and properties are defined which determine the models and methods of its solution. Disciplines of applied tasks stream maintenance. In the course of DCS functioning there were defined two groups of tasks: applied and operational tasks. The order of solving the operational tasks depends on entering way of the applied tasks for maintenance. That is why the discipline of stream maintenance of applied tasks solved at DCS is defined preliminarily. If DCS is considered as the system of applications maintenance (i.e., applied tasks) then the applications maintenance discipline depends on the characteristic of input flow and the speed of its maintenance λ, μ, Ts, where λ - intensity of aplied tasks entering for maintenance; μ - intensity of maintenance of applied tasks having been entered, Ts – DCS delay interval.

Dependent on ratio of these and other parameters there are possibly two following versions of applied tasks maintenance discipline in practice:

1) lists of tasks being solved at DCS are either known beforehand and preset with their characteristics or attributes;

2) in the course of system operation there entered the tasks with various characteristics or attributes sporadically.

We assume that applied tasks are not interrelated.

Let's consider version 1 of applied tasks flow maintenance according to which maintained applied tasks are preliminarily put in order into the maintenance queue.

Let DCS is preset and a number of applied tasks shall be solved at it:

$$Zd = \{Zd1, Zd2, \ldots, Zdi, \ldots, Zdn\},$$

at that, time-ordered by parameters of solution process

$$<Zd> = <Zd1, Zd2, \ldots, Zdi, \ldots, Zdn>,$$

which shall be solved at DCS in succession.

Every task is characterized by its attributes

$$\chi(Zdi) = (\chi Zi1, \chi Zi2, \ldots, \chi Zij, \ldots, \chi Zin).$$

A part of them is static and another one is dynamic. Static attributes of applied tasks are: required degree of protection, operability, security (reliability) of their solution. These attributes are set with the person making decision (PMD) within the period of task formation. Tasks dynamic attributes are defined in the course of tasks solution. For instance, a dynamic attribute of Zdi task is the attribute when Zdi task solution is reached by execution of computational process ВПi at DCS with a definite time length (starting time and duration of the task solution, time end point).

The given relevance will be shown as:

$$Zdi(t) \rightarrow \text{ВП}i(t),\ t \in [tiS, tiF] \in [TiH, Ti\text{К}],$$

where: tiS, tiF – starting and ending point of execution, ВПi, TiH, TiК – starting time and time end point of Zdi task solution.

Requirements to computational processes in particular to ВПi of Zdi task fuflilled at DCS: КТ = (Нп, Оп, Пл, Тч, От, Эф) or

$$\text{КТ}(Zdi) \rightarrow (\text{Нп}(Zdi),\ \text{Оп}(Zdi),\ \text{Пл}(Zdi),\ \text{Тч}(Zdi),\ \text{От}(Zdi),\ \text{Эф}(Zdi)) \qquad (1)$$

where Нп - principle of continuity, Оп - operability, Пл - completeness, Тч - accuracy, От – absence of information leakage, Эф – efficiency.

These requirements are named as qualitative ones to the task solution result. Minimal (lower – H) level of these requirements fulfillment for Zdi is characterized by indicators value: $\text{КТН}(Zdi) \rightarrow (\text{НпН}(Zdi),\ \text{ОпН}(Zdi),\ \text{ПлН}(Zdi),\ \text{ТчН}(Zdi),\ \text{ОтН}(Zdi),\ \text{ЭфН}(Zdi))$.

Fulfillment of requirements (1) is reached by operational tasks solution.

DCS operation tasks analysis

DCS is designed to support computational processes of applied tasks. At that computational processes of the tasks shall be executed in the way to fulfill the tasks conditions (1).

Implementation of those conditions is reached by DCS operational tasks solution. In the course of DCS operation there appear a number of problems involving the main processes of DCS operation:

$$ZE = (Ze1, Ze2, Ze3,\ldots, Zeh,\ldots, Zem,),$$

where Ze1,Ze2,Ze3 are planning problems; Ze4,Ze5,Ze6,Ze7,Ze8,Ze9,Ze10 – problems of control:

Ze1 – planning of applied tasks.

Ze2 – planning of applied tasks computational processes;

Ze3 - planning of DCS functionality for execution of applied tasks;

Ze4 – control over computational processes of applied tasks.

Ze5 - control over DCS functionality (for instance, server, station, network equipment, finite system);

Ze6 - control (or provision) over DCS functionality.

Ze7 – control over DCS functional resources;

Ze8 – control over the system functionality quality and solution of applied tasks (for instance, service quality);

Ze9 – control over DCS development: quality, functionality, resource;

Ze10 – control over correct actions of a man at DCS.

Each of the mentioned tasks is decomposed into subtasks.

Versions of statement and/or formulation of every Zdi–i-task depend on statement and/or formulation of other Zdj tasks, $j=1,n$, $j\neq i$, $i\in N$, on the way of boundary conditions setup. At that domain of definition of those tasks can be defined by PMD (based on exogenous factors, i.e., for Zeh task the domain of definition $\vartheta(Zeh)$ and its boundary $\overline{\vartheta}(Zeh)$ can be defined by PMD. At that it is possible that for Zei and Zej the domains of their definitions $\vartheta(Zei)$ and $\vartheta(Zej)$ can be covered $\vartheta(Zei)\cap\vartheta(Zej)\neq 0$. So the boundary $\vartheta(Zei)$, $\overline{\vartheta}(Zej)$ and magnitude of coverage between $\vartheta(Zei)$ and $\vartheta(Zej)$ tasks domain i.e., value $\Delta\vartheta(Zei,Zej)=\vartheta(Zei)\cap\vartheta(Zej)$ can be defined by PMD, proceeding from peculiarities of DCS functionality provision processes.

It should be noted that the tasks domain of definition and their importance is determined proceeding from correlation between the tasks which can be represented as a graph: G = (R, ZE) where R – relations between the tasks from ZE. Relations can be causal (R1), corollary (R2), important or preferable (R3) for selected strategy of operation or provision of functionality.

Such characteristics of operational tasks as:

1) domain of definition, 2) importance; 3) source; 4) dependence between them

defined,

- either PMD (or supersystem) on the assumption of preset control strategy and fulfillment of applied tasks computational processes,
- or a developer (during designing) by means of analysis of operational processes and character of applied tasks solution.

Based on tasks characteristics there constructed models and methods of operational tasks control including DCS functionality provision tasks on the basis of which DCS functionality control systems are designed.

Thus in the course of DCS operation there appears a number of problems the solution of which secures its functionality and fulfillment of applied tasks computational processes (which proceed from supported business process).

However simultaneous achievement of high level execution of all enumerated tasks is difficult. Such complete version of operation task statement we call as the task of maximal operation or maximal operational task.

In practice the maximal task is reduced.

It is reduced in particular in the following way.

Among denoted problems the main task of $OZei\in ZE$ task can be taken from any of them (is defined by PMD). Different versions are possible.

1. Hereby only one task is being considered and complete operational task is reduced to FZE→OZei task. The given version is called minimal operational task.

2. The main OZei task is accepted as a backbone one for overall process of DCS control and DCS operation process. Then upon occurring the problem FZE task solution consists of two stages:

first and foremost it is the solution of OZei main task;

afterwards the second part of FZE task solution comes down to the solution of tasks set ZE´ = ZE/OZei, which are represented as a sequence setup in the definite way:

$$\langle ZE'\rangle \rightarrow \langle Ze1, Ze2, Ze3,\ldots, Zej,\ldots, Zep\rangle$$

or as

$$\langle ZE'\rangle \rightarrow \langle Ze1\rightarrow Ze2\rightarrow Ze3\rightarrow,\ldots,\rightarrow Zej\rightarrow,\ldots,\rightarrow Zep\rangle.$$

Criteria for putting the tasks in order can be causal, operational or informational dependence between the tasks.

Putting the problems in order can be static or dynamic. Selection of ordering version depends on features of DCS functionality which in its turn depends on its components makeup, structure and architecture as well as on the media of its functionality.

Analysis of DCS functionality control tasks

Among operational problems there will be considered the task of functionality provision, i.e., the task of DCS functionality control. Level of DCS functionality is defined with properties set:

- reliability (H), appropriate for securing the continuity of the applied task solution,
- protection of inner resources (N),
- safety (Q),
- correctness (K),
- DCS functionality productivity (G),
- DCS observability (Нб),
- DCS controllability (Уп),
- DCS robustness (Ус),
- convergence property of DCS control process (Сх) and DCS functionality efficiency (Эф).

Quantity and magnitude of every property fulfillment defines the level of DCS functionality.

At that these properties belong to both separate components and to the system as a whole.

The task directed towards maximal implementation of requirements to all DCS functionality properties will be named a maximal DCS functionality task. These requirements will be named the meta-requirements (MT) to execute applied task.

However simultaneous achievement of high level execution of all enumerated tasks is a difficult one. That is why upon solving the functionality tasks in practice the maximal task is reduced. One of the versions of DCS functionality task reduction is as follows.

Definition 1. DCS involves the functionality for solving the current acute applied task $\forall Zdi \in ZD$ in minimum, if it possesses the properties $\Psi=(H, N, Q, K, G)$, sufficient for complete solution of the task $\forall Zdi \in ZD$ within its life time (tiS, tiF).

It is assumed that the properties are measured in the definite metrics and scale of measurement.

The degree of implementation of every property is characterized by an indicator $\Psi=(PH, PN, PQ, PK, PG)$.

Therefore to solve every Zdi task it is necessary that DCS possesses minimal levels of functionality on every property.

$Zdi \in \Psi H(Zdi)=(PHH(Zdi), PHN(Zdi), PHQ(Zdi), PHK(Zdi), PHG(Zdi))$.

Definition 2. For Zdi task the requirement to $\Psi(Zdi)$ implementation is MT (meta requirements) of Zdi task, and KT are quality requirements.

At the moment the indicator value of functionality Ψ is defined:

$\Psi(t) = F(H(t), N(t), Q(t), K(t), G(t)) = \alpha 1H(t)+\alpha 2N(t)+\alpha 3Q(t)+\alpha 4K(t)+\alpha 5G(t)$,

where $\Sigma\alpha i = 1$, magnitude αi is defined proceeding from meta requirements.

Definition 3. DCS is functional for actual task in case the level of its functionality corresponds to MTrequirements throughout its life time.

In the course of fulfilling the computational processes 1) MT magnitude is altered, 2) DCS functionality level is changed due to random factors. Therefore to achieve the required level of functionality and its stabilization there is a resource both in DCS itself and outside it.

Therefore proceeding from meta requirements denoted in the applied task there is followed DCS functionality control task based on existing functional resources.

Based on meta requirements makeup the structure of DCS functionality at the moment will be defined in the following way:

$\Psi(t) = F(H(t), N(t), Q(t), K(t), G(t)),=F(\{\Psi i(t): i=1,5\})$,

where $\Psi(t)$ – current indicator of functionality, H(t) – indicator of reliability, N(t) – indicator of protection, Q(t) – indicator of safety, K(t) – indicator of correctness, G(t) – indicator of efficiency.

Formulation of DCS (ZF) functionality control task will be implemented from defining DCS conditions components different combinations of which create different aspects and consequently DCS functionality control task formulation. Status and form of inclusion of these components into the task structure depend on their measurement means as well as on boundary conditions of DCS functionality space spanned by the given task. Boundary conditions of the given task are formed by other problems of operational period of DCS.

Based on the assumption that the rest components are formulated by other operational tasks we distinguish the following components makeup the combination (IZ) of which defines various aspects of DCS functionality control task:

$IZ=\{MP(t), ZD(t), B\Pi(t), C(t), \xi(t), PC(t), CZ(t), MT(t), KT(t), \Psi(t), \Psi R(t), (t)\}$,

where: MP(t) – DCS model for functionality task; ZD(t) – multiplicity of applied tasks solved in (tS, tF) time interval at DCS: $ZD=\{Zd1,Zd2,\dots,Zdi,\dots,Zdn\}$; tS – starting time, tF – finite time; $B\Pi(t)$ – graph model of computational processes ($B\Pi$) of ZD and Zdi tasks; C(t) – controlled DCS state; $\xi(t)$ – incident occurred at DCS; PC(t) – pathologic processes appeared at DCS due to $\xi(t)$; CZ(t) – goal state of DCS functionality, $CZ(t)=<CZj\ CK(CZj)>$, CZj – instance identifier CZ(t), CK(CZj) – characteristics; $\Psi(t)$, $\Psi R(t)$, W(t)– functionality level and resources, functionality criteria, where $\Psi R(t)$ possesses the characteristics: $\Psi R(t)=<\tau(t), Q(t)\ Dc(t), Th(t), Ng(t)>$ – characteristics of functional resources, where: $\tau(t)$ – existence duration, Q(t) – volume, Dc(t) - accessibility, Th(t) – producibility; $W(t)=(Wi(t): i=1,5)$ – general and particular criteria of: reliability, protection, safety, robustness, DCS efficiency.

Scheduled processes including computational ones executed at DCS and pathologic processes create jointly current DCS states which are represented as C(t).

Life span of applied task $ZD\in\{Zd1,Zd2,\dots,Zdi,\dots,Zdn\}$ is defined for every Zdi by the interval (tiS, tiF), where: tiS, tiF – starting and finite time of Zdi.

We will select one of task formulation versions of DCS functionality control task.

Process of ZF functionality task solution consists of several stages. All life span periods of ZF task consist of following key moments:

- till incident occurrence (tn–) (stage of normal state),
- moment of incident occurrence (tn) (pathology phase),
- after incident occurrence (tn+) (restoration phase).

The task of DCS functionality control appears when requirements and conditions to ZD solution are troubled.

Functionality shall be controlled upon:

- occurrence of incorrectness in DCS construction itself (constructive factor);
- hazardous factor of outer media, i.e. upon disturbance of DCS functioning and operation mode due to incident;
- changing the tasks characteristics, i.e., meta requirements.

At that functional resources presenting resources allowing realization of goal and control solution can be closed and open, entering from outside.

It is assumed that ZF task due to occurrence cause is version 1-3.

Theoretically there are three possible versions of identification of state in ZF task formulation through definitions:

- incident $\xi(t)$,
- state consequence PC(t) caused by incident $\xi(t)$,
- trouble of fulfillment of conditions MT(t) and KT.

In formulation let’s accept identification version $\xi(t)$ via PC(t) influenced at DCS elements state.

ZF task is formulated based on components (1.1) in the way:

1. Let the initial state and DCS conditions IZ task be:

- state is setup as C(t) or $C(t)=\{Ci(t)\}$;

- there are three time moments for the task: tn–, tn, tn+;
- let the initial state of corporate information system (CIS) at tn moment–=t be as C(t)∈CZ, at that Wc = <w1c,w2c,…,wic,…,wnc>. We name it as pre-incident state;
- resources stock: ΨR(t).

2. Let the fact C(t) ∉ CZ has been found at tn=t moment which conforms to the fact that: ∃wi∈W = (wi(t)<wic), where wi∈W = {T(Hп), T(Oп), T(Пл), T(Тч), T(Эф)}.

Then:

1) According to DCS states for every time interval (tn+, t′n+) measured for every time interval: τ1: <C(tn+τ1), C(tn+2τ1),…, C(tn+kτ1), …, C(tn+mτ1)>.

at t′n+ interval it is necessary to define pathology availability if any PC(t) and its characteristics: χ(PC(t)) = (χP1,χP2,…,χPi,…,χPn) at (t′n+-tn)→ min.

2) Based on characteristics χ(PC(t)) = (χP1,χP2,…,χPi,…,χPn) it is necessary to identify the type and copy ξ(t) at t′n+ moment at (t′n+-t′n+)→ min.

3) Based on <ξ(t), ΨR(t)> it is accepted that such new goal state CZн (new), which secures fulfillment of the condition (Mтi - wi) → min, i=1,n.

4) Determine at DCS CZн, whereupon it is necessary to minimize consumption of: time, resources, Δψi → min: i=1,n value.

5) To define such controlling conditions U which secure the selected CZн state at DCS

To setup such CIS Cн(t′′′n+) state at t′′′n+ moment for which conditions Cн(t′′′n+)→CZн, U,) and qi→min, i=1,n. are fulfilled based on (C(t)∈CZOK, U, CZн)

One of the criteria is time consumption minimization for DCS transfer from current state to the domain of selected goal state represented as: qi=(t′′′n+ - t′′n+)→min, where CZOK –CZ, CZ∈CZOK surrounding, t′′′n+ - time of ZOK new state setup.

Different components with various combinations can be used out of IZ components makeup for the task implementation. For instance, for (tn–, tn) period current states for the task can be set up as follows: C(t)→<MP(t), BП(t), ξ(t), PC(t), ΨY(t)>, C(t)→<BП(t), ξ(t), PC(t)>, C(t)→<ξ(t), PC(t)>. At that different combinations of IZ components makeup can be used as prognosis state, ex.:

Cпр(t)→<MP(t), ZD(t), BП(t), C(t), ξ(t), PC(t), CZ(t), ΨR(t), MT(t), KT(t), W(t)>,

Cпр(t)→<C(t), ξ(t), PC(t), CZ(t), ΨR(t), MT(t), KT(t), W(t)>,

Cпр(t)→<PC(t), CZ(t), ΨR(t), MT(t), KT(t), W(t)>.

Selection of any version of DCS state representation depends on the DCS properties features, on strategy and goal of control and on the requirements to DCS control processes completeness.

DCS states are defined by collection of states of separate modules each of which implements certain operations of computational processes Mi module state of Oпi of computational process is defined by DCS as: C(t) = <A1, A2, A3, A4>, where: A1 – module identification code fulfilling Oпi∈BП operations; A2 – working parameters values; A3 – testing parameters values; A4 – parameters characterizing functionality (Н, З, Б, К, П), computed according to functionality dependence models/formulas.

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