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MAXIMAL PROFIT SERVICE TASK PARTITION AND ALLOCATION IN COMPUTER GRID CONSIDERING SERVICE RELIABILITY AND SECURITY

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ABSTRACT

The paper considers grid computing systems in which the resource management systems (RMS) divides a service tasks into execution blocks (EBs) and sends these blocks to different available resources. The service cost comprises the task execution cost, communication cost and security measures cost and depends on the resources assigned to execute the EBs. The service price is determined according to a fixed tariff. The pricing approach is considered: price based on service time and penalties for service reliability and security failures price depending on service and expected security level. The optimal task partition and distribution should maximize the provider's profit, which is equal to the difference between the service price and its cost for the provider. The paper suggests an algorithm for solving the profit optimization problem. The algorithm is based on the universal generating function technique and on the evolutionary optimization approach. Illustrative examples are presented.

Keywords: *Grid System, Service Price, Service Reliability, Service Security, Service Cost, Subtask Distribution, Universal Generating Function*

1. INTRODUCTION

With the rapid development of computer network and distributed computing, people's needs for computing power have become so high that separate computing systems cannot satisfy them[1]. Thus, grid computing, which solves the challenging tasks via coordinated resource sharing in distributed dynamic, multi-institutional virtual organizations, is emerged [2].

The resource sharing is controlled by a Resource Management System (RMS) [3]. When the RMS receives a service request from a user, the task can be divided into a set of execution blocks (EBs) that are executed in parallel. The RMS assigns those EBs to available resources for execution. After the resources finish the assigned jobs, they return the results back to the RMS and then the RMS integrates the received results into entire task output which is requested by the user.

The above grid service process can be approximated by a structure with star topology, where the center is the RMS directly connected with the resources through respective communication channels.

The performance of grid computing is of great concern [4]. Usually the measure of grid performance is the task execution time (service time). This index can be significantly improved by using the RMS that divides a task into a set of EBs which can be executed in parallel by multiple online resources. Many complicated and time-consuming tasks that could not be implemented before are currently working well under the grid computing environment.

The service time is a random variable affected by many factors [5]. As the service time is one of the major characteristics of the quality of service, the service tariffs established by the providers usually include dependency on the time elapsed between the service request arrival and the entire task completion. Thus the provider must strike the balance between the performance, reliability, security of the service task and its cost. This paper presents an algorithm that finds the service task partition and distribution among the resources that maximize the provider's profit considering service reliability and data security constraints.

Section 2 of the paper presents the grid service expected time, cost reliability and security model. Section 3 describes an algorithm to efficiently obtain the service time distribution by using universal generating function technique. Section 4 provides illustrative examples and section 5 concludes.

Nomenclature

B_j	set of numbers of input data blocks necessary for performing subtask *j*
c_k	computational complexity of subtask *k*
C_i	computational complexity of EB *i*
d_i	probability of security failure of EBi
D_i	amount of data transferred between RMS and resource *i*
e_R	penalty coefficient for insufficient reliability
e_Y	penalty coefficient for insufficient security
g	total number of available resources in the grid
h	total number of different EBs formed by the RMS
I_x	amount of data in input data block *x*
m	total number of subtasks
n	total number of input data blocks
O_j	amount of subtask j output data
P	expected profit of service provider
Pr(*e*)	probability of event *e*
R	service reliability
R^*	minimal allowed service reliability
s_j	data transmission speed (bandwidth) of communication channel *j*
t_{ij}	*random time of EB i completion by resource j*
$u_{i,\omega}(z)$	universal generating function (u-function) representing probability mass function (pmf) of $\theta_{i,\omega}$
$U_k(z)$	u-function representing pmf of function $\max\limits_{1\le i\le k}\theta_{i,\omega_i}$
V_c	total cost of using communication channels
V_r	total cost of using resources
V_s	total cost of security measures during using resources and channels
w_l	price of service for $\Theta_l \min < \Theta \le \Theta_l \max$
W	random price of service
x_j	processing speed of resource *j*
y_k	insecurity (probability of unauthorized access(UA)) of resource *k* and communication channel *k*
Y_δ	insecurity of δ-th sensitive data task groups (SDTG) (probability of UA to data associated with each subtask belonging to SDTG)
Y_δ^*	maximum allowed level of Y_δ
α_j	cost of using resource *j* per time unit
βj	cost of using communication channel *j* per time unit
γ_j	cost of security measures applied to resource j and channel *j* per time unit
δ	number of SDTG
Δ	total number of SDTGs in the service task
$\theta_{i,\omega}$	random time of EB *i* completion by resources belonging to set ω
θ^*	maximal allowed service time that users presents
Θ	random service time
l	number of service time interval
L	total number of time intervals defined in the tariff
Θ_l^*	limit of service time interval *l*, *l*=1,…,L. $\Theta^*_{l-1} < \Theta^*_l$
λ_j	failure rate of resource *j*
π_j	failure rate of communication channel *j*
σ_i	set of subtasks composing EB *i*
ψ_δ	set of tasks composing δ-th SDTG
ωi	set of resources processing EB *i*
1(x)	unity function: 1(TRUE) = 1, 1(FALSE) = 0

2. THE MODEL

2.1 Service Execution By The Grid Computing Architecture

The considered service can use a given set of resources distributed in the grid system. All the resources and communication channels from this set are available at the time when the request for service arrives to the RMS (unavailable resources are detected by the RMS and, thus, not involved in the service). Different models for evaluating the vulnerability of software operating systems can be found, for example, in [6,7].

The service task consists of subtasks that can be independently executed by different resources. Each subtask is characterized by a fixed complexity, a fixed amount of output data and a fixed set of input data blocks necessary for the subtask execution. Different subtasks may need some common input data blocks for their execution. The subtasks can be grouped into execution blocks (EBs). The input data for any EB consists of input data blocks necessary for executing all the subtasks belonging to this EB.

The request for service (task execution) arrives to the RMS which forms the EBs and assigns them to different resources for processing. Each resource gets no more than one EB for processing. But one EB can be assigned to several resources for parallel execution. If the same EB is processed by several resources, it is completed when first output is returned to the RMS. The entire task is completed when all of the EBs are completed and their results are returned to the RMS from the resources.

The resource is involved in data exchange process. If resource failure or communication channel failure occurs before the end of output data transmission from the resource to the RMS, the execution of the corresponding EB fails (cannot be completed). Execution of some subtasks is associated with transferring and/or processing sensitive data. The UA to this data constitutes the security failure of service. The security failure occurs if sensitive data is processed by a resource or transmitted by a channel when UA to the resource or channel is accomplished.

Some data sets can be useful only in their integrity (for example, encoded data can be used only if the decoding algorithm is available). Sensitive data task groups (SDTG) can be introduced to represent the data access dependency. Each SDTG represents a set of subtasks. In order to use the information one has to get access to data (input or output) associated with all subtasks belonging to SDTG.

Using each resource (communication channel) is associated with providers' expenditures that are proportional to the estimated time of EB execution (data transmission). During this time the resource (channel) cannot be used for other tasks and, therefore, the full usage cost is inflicted even if the resource (channel) fails during the task execution. The failures occur independently from task distribution in the grid and, therefore, the repair cost does not depend on resource assignment and is not considered in this paper.

The service price is determined by a fixed tariff such that different prices correspond to different service time intervals and different provided service reliability and security levels.

2.2 Assumptions

(1) Each resource starts processing the assigned EB immediately after it gets all the necessary input data from the RMS through the corresponding communication channel. Each resource sends the output data to the RMS through the same communication channel immediately after it completes the EB.

(2) Each resource has a given constant processing speed when it is available. Each resource has a given constant failure rate.

(3) Each communication channel has constant data transmission speed (bandwidth) when it is available. Each communication channel has a constant failure rate.

(4) The subtasks belonging to an EB are processed in sequence. The subtask processing time is proportional to its computational complexity.

(5) The data transmission time is proportional to the amount of data transmitted between the RMS and a resource.

(6) The failure rates of the communication channels or resources are the same when they are idle or loaded (hot standby model). The failures at different resources and communication channels are independent.

(7) The RMS is fully reliable. The time of task processing by the RMS (formation and assignment of EBs, sending them to the resources, receiving the results and integrating them into entire task output) is negligible when compared with the EBs' processing time.

(8) The costs of using resources (communication channels) are proportional to the estimated time of corresponding EB execution (data transmission). Each resource and channel is characterized by a fixed per time unit cost.

(9) Service security failure b occurs if all EBs containing subtasks belonging to b-th SDTG are accessed by unauthorized person.

(10) The UA to different resources/channels are independent events.

(11) The probability of UA depends on the protection level of resource and its communication channel and does not depend on the amount of data processed and type of task performed by the resource.

2.3 Random Service Time

According to the assumptions the entire task consists of a set Φ of m subtasks that can be executed independently. These subtasks can be partitioned into a collection of h mutually disjoint subsets σ_i, i.e. such that

$$\bigcup_{i=1}^{h}\sigma_i = \Phi\ ,\ \ \sigma_i \bigcap \sigma_k = ø,\ i\neq k. \tag{1}$$

Each set can contain from 0 to m elements. If $|\sigma_i|=m$ and $|\sigma_j|=0$ for any $j\neq i$, all of the subtasks form a single EB, if $h=m$ and $|\sigma_i|=1$ for any i, all of the subtasks are separated (executed by different resources). The total number of EBs (nonempty subsets σ_i) h cannot be greater than m.

The allocation of h EBs among g resources ($g\geq h$) is also a problem of partitioning a set Ω of g resources into a collection of h mutually disjoint subsets ω_i.

$$\bigcup_{i=1}^{h}\omega_i = \Omega,\ \ \omega_i \bigcap \omega_j = ø,\ i\neq j. \tag{2}$$

Note that h also cannot be greater than g.

Any EB i consisting of a set of subtasks σ_i has computational complexity

$$C_i = \sum_{j=1}^{m} c_j 1(j\in\sigma_i)\ . \tag{3}$$

Each subtask j needs a set B_j of data blocks as its input and produces amount O_j of output data. The set of the input data blocks necessary for execution of EB i is $\cup_{j\in\sigma i} B_j$ and therefore, the amount of data to be transmitted from the RMS and the resource executing this EB is $\Sigma^n_{x=1} I_x 1(\ x\in\cup_{j\in\sigma i}\ B_j\ )$. The total amount of data (input and output) D_i that should be transmitted between the RMS and a resource executing EB i is

$$D_i = \sum_{j=1}^{m} O_j 1(j\in\sigma_i) + \sum_{x=1}^{n} I_x 1(x\in \bigcup_{j\in\sigma_i} B_j)\ . \tag{4}$$

The EB execution time is defined as time from the beginning of input data transmission from the RMS and a resource to the end of output data transmission from the RMS and the resource. Here we call it "EB i can be successfully completed by resource j" if this resource and communication link j do not fail before the end of subtask execution. Therefore, the random time t_{ij} of EB i completion by resource j can take two possible values

$$t_{ij} = \begin{cases} \hat{t}_{ij} = \dfrac{C_i}{x_j} + \dfrac{D_i}{s_j}, \text{if EB } i \text{ can be successfully} \\ \qquad\qquad\qquad \text{completed by resource } j \\ \infty, \text{otherwise} \end{cases} \tag{5}$$

For constant failure rates of resource j and communication link j one can obtain the probability of EB success as

$$p_j(\hat{t}_{ij}) = e^{-(\lambda_j+\pi_j)\hat{t}_{ij}} \tag{6}$$

These give the distribution of the random EB execution time t_{ij}: $Pr(\ t_{ij}=\ \hat{t}_{ij}\ )=p_j(\ \hat{t}_{ij}\ )$ and $Pr(\ t_{ij}=\infty\ )=1-\ p_j(\hat{t}_{ij})$.

Assume that each EB i is assigned to resource s composing set ω_i such that $\omega_i\cap\omega_j=\phi$ for any $i\neq j$. In this case the random time of EB i completion is

$$\theta_{i,\omega_i} = \min_{j\in\omega_i}(t_{ij})\ . \tag{7}$$

The entire task is completed when all of the subtasks (including the slowest one) are completed. Therefore the random task execution time takes the form:

$$\Theta = \max_{1\leq i\leq h}\theta_{i,\omega_i} = \max_{1\leq i\leq h}[\min_{j\in\omega_i}(t_{ij})]\ . \tag{8}$$

Having the distributions of each random time t_{ij} one can obtain the distribution of the entire service execution time Θ (probability mass function of discrete variable Θ) in the form of pairs (Θ_f, Q_f), $0\leq f\leq F$ where Θ_f is f-th realization of Θ, $Q_f = Pr(\Theta = \Theta_f)$ and F is total number of different realizations of Θ.

Since the task execution time (service time) Θ can take different values, the service should be considered as a multi-state system with performance depending on combination of states of its elements (different combinations of available and failed resources and communicational channels correspond to different values of service time).

2.4 Service Reliability In A Grid System

In applications where the execution time of each task (service time) is of critical importance, the system reliability $R(\theta^*)$ is defined (according to performability concept [8,9]) as a probability that the correct output is produced in time less than θ^*. This index can be obtained as

$$R(\theta^*) = \sum_{f=1}^{F} Q_f \cdot 1(\Theta_f < \theta^*). \qquad (9)$$

2.5 Data Security In A Grid System

When EB i is executed by a set of resources ω_i, the UA to any one of the resources belonging to ω_i causes the security failure of this EB. If the insecurity of resource k is y_k the probability of security failure of EB i can be represented as

$$d_{\mathrm{i}} = 1 - \prod_{k=1}^{g} \left(1 - y_k\right)^{1(k \in \omega_i)}. \qquad (10)$$

The UA to data associated with subtasks from SDTG δ succeeds if data blocks associated with all tasks belonging to the set ψ_δ are accessed. As each subtask belongs to no more than one EB, all EBs containing at least one subtask from ψ_δ must be accessed. The probability of the security failure of all the EBs containing at least one subtask from ψ_δ can be obtained as

$$Y_\delta = \prod_{i=1}^{h} \left(d_i\right)^{1(\psi_\delta \cap \sigma_{\mathrm{i}} \neq \varphi)}$$
$$= \prod_{i=1}^{h} \left(1 - \prod_{k=1}^{g} \left(1 - y_k\right)^{1(k \in \omega_{\mathrm{i}})}\right)^{1(\psi_\delta \cap \sigma_{\mathrm{i}} \neq \varphi)}. \qquad (11)$$

2.6 Service Cost In A Grid System

The total cost of using the resources assigned to execute EBs is

$$V_r = \sum_{1 \le i \le h} \sum_{j \in \omega_i} \alpha_j \frac{C_i}{x_j}. \qquad (12)$$

The cost of using the communication channels is

$$V_c = \sum_{1 \le i \le h} \sum_{j \in \omega_i} \beta_j \frac{D_i}{s_j}. \qquad (13)$$

The cost of security measures during using resources and channels is

$$V_s = \sum_{1 \le i \le h} \sum_{j \in \omega_i} \gamma_j \left(\frac{C_i}{x_j} + \frac{D_i}{s_j} \right) \qquad (14)$$

2.7 The Penalty Approach For Obtaining Service Price And Expected Profit

The service tariff establishes the dependence between its price W and time Θ in the following form: $W=w_l$ when $\Theta_{l-1}^* < \Theta \le \Theta_l^*$ for $l=1,\dots, L$ where L is the number of time intervals defined in the tariff and $\Theta_0^*=0$, $\Theta_L^*=\infty$. The penalty coefficients e_R, e_Y are introduced when service reliability and security fail to meet the fixed constraints.

Having the distribution of the service time Θ in the form (Θ_f , Q_f), $0 \le f \le F$, one can obtain the expected service price that the provider charges the user

$$E(W) = \sum_{l=1}^{L} w_l \sum_{f=1}^{F} Q_f \cdot 1(\Theta_{l\text{-}1}^* \le \Theta_f < \Theta_l^*)$$
$$-e_R \left(R^* \text{-} R(\infty)\right) \cdot 1\left(R(\infty) < R^*\right)$$
$$-e_Y \cdot \frac{1}{\Delta} \sum_{\delta=1}^{B} \left(Y_\delta - Y_\delta^*\right) \cdot 1\left(Y_\delta > Y_\delta^*\right)$$

(15)

Having the $E(W)$ defined in (15) one obtains the expected provider's profit as

$$P = E(W) - V_r - V_c - V_s \qquad (16)$$

3. ALGORITHM FOR DETERMINING THE PMF OF THE SERVICE TIME

The procedure used for the evaluation of service time distribution is based on the universal generating function (u-function) technique, which was introduced in [10] and which proved to be very effective for the reliability evaluation of different types of multi-state systems [13]. The main advantage of this technique is its high computational efficiency that allows it to be used in optimization procedures where a large number of different solutions should be estimated.

3.1 Universal Generating Function Technique

In the case of grid systems, the u-function $u_{i,\{j\}}(z)$ can define pmf of total completion time t_{ij} for EB i assigned to resource j. This u-function takes the form of

$$u_{i,\{j\}}(z) = p_j(\hat{t}_{ij}) z^{\hat{t}_{ij}} + [1 - p_j(\hat{t}_{ij})] z^{\infty}, \qquad (17)$$

where $t\hat{}_{ij}$ and $p_j(t\hat{}_{ij})$ are determined according to Eqs. (5) and (6) respectively.

.The u-function representing the pmf of completion time $\theta_{i,\omega i}$ of EB i assigned to all of the resources from set $\omega_i = \{k_1, \dots ,k_n\}$ can be obtained recursively using composition operator $\otimes_{\min}$ according to (7):

$$\begin{aligned} &u_{i,\{k_1,k_2\}}(z) = u_{i,\{k_1\}}(z) \underset{\min}{\otimes} u_{i,\{k_2\}}(z), \\ &u_{i,\{k_1,k_2,k_3\}}(z) = u_{i,\{k_1,k_2\}}(z) \underset{\min}{\otimes} u_{i,\{k_3\}}(z), \\ &\ldots, \\ &u_{i,\omega_i}(z) = u_{i,\{k_1,\ldots,k_n\}}(z) \\ &= u_{i,\{k_1,\ldots,k_{n-1}\}}(z) \underset{\min}{\otimes} u_{i,\{k_n\}}(z). \end{aligned} \quad (18)$$

Having the u-functions $u_{j,\omega j}$ (z) for each EB i ($1 \le i \le h$) one can obtain the u-function representing the pmf of the entire task completion time Θ using composition operator $\otimes_{\max}$ according to Eq. (8).

$$\begin{aligned} &U_1(z) = u_{1,\omega_1}, \\ &U_2(z) = U_1(z) \underset{\max}{\otimes} u_{2,\omega_2}(z), \\ &\ldots, \\ &U_h(z) = U_{h-1}(z) \underset{\max}{\otimes} u_{h,\omega_h}(z). \end{aligned} \quad (19)$$

The final u-function $U_h(z)$ represents the pmf of random task completion time Θ in the form

$$U_h(z) = \sum_{f=1}^{F} Q_f z^{\Theta_f}. \quad (20)$$

The service reliability and expected service price can be obtained from this pmf using Eq. (9) and (15).

3.2 Algorithm For Determining The Provider's Profit For Arbitrary Task Partition And Allocation σI,ωI (1≤I≤H)

1. For the given task partition σ_i ($1 \le i \le h$) determine C_i and D_i for each EB i using (3) and (4).
2. Assign $V_r = V_c = 0$.
3. For each EB i ($1 \le i \le h$) with $\sigma_i \ne \phi$:
3.1. For each $j \in \omega_i$ add α_j (C_i/x_j) to V_r and β_j (D_i/s_j) to V_c.
3.2. For each $j \in \omega_i$ determine $\hat{t}_{ij}$ according to Eq. (5), $p_j(\hat{t}_{ij})$ according to Eq. (6) and $u_{i,\{j\}}(z)$ according to Eq. (17).
3.3. Determine $u_{i,\omega_i}(z)$ using the recursive procedure (18).
3.4. Determine the probability of security failure d_i using (10)
4. Determine $U_h(z)$ using recursive procedure (19).
5. For each SDTG δ ($1 \le \delta \le \Delta$) represented by set ψ_δ obtain Y_δ using (11)
6. Determine R and $E(W)$ using Eq. (9) and Eq. (15) respectively.
7. Determine the provider's profit P using (16).

Formulation (16) defines a complicated NP complete partitioning/allocation problem. Considering reasonable time limitations, we propose the genetic algorithm (GA) rather than an exhaustive examination of all possible solutions.

To apply the genetic algorithm to a specific problem, a solution representation and decoding procedure must be defined [11]. Crossover and mutation procedures should preserve feasibility of newly obtained solutions given that parent solutions are feasible (constitute permutations). A crossover procedure that was suggested in [12] and was proven to be highly efficient in [13] is used in this work.

4. NUMERICAL EXAMPLES

Consider a grid service that uses six resources distributed in the grid system. Parameters of grid resources and the corresponding communication channels (processing/transmission speeds, failure rates, insecurity and per time unit costs) are presented in Table 1. The entire service task can be divided into eight independent subtasks. The computational complexity, the amount of output data and the list of input data blocks for each subtask are presented in Table 2. The amount of data in each input data block is presented in Table 3.

The structure and security constraints for three different SDTGs are presented in Table 4. The solutions of the profit optimization problem $P = E(W) - V_r - V_c - V_s \rightarrow \max$ for $R^* = 0.96$, Y_δ^* ($1 \le \delta \le \Delta$) from Table 4 and different tariffs from Table 5 are presented in Tables 6 and 7.

Three cases are analyzed in the example. First, the case when the service reliability is critical whereas service security is neglected is expressed by incurring considerable penalty e_R and assigning $e_Y = 0$. In this case the provider tends to increase the parallelization to achieve higher service reliability, as it makes more replicas of the same data to be transmitted/processed in the distributed grid and, therefore, increases the chances of UA to the data.

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Table 1. Parameters Of Grid Resources And Communication Channels

No of resource (channel) j	λ_j (sec^{-1})	x_j (Moperations/sec)	π_j (sec^{-1})	s_j (Mbytes/sec)	Insecurity y_j	Execution cost per sec	Communication cost per sec	Security maintenance cost per sec
1	0.0001	10	0.0010	3	0.10	0.09	0.30	0.09
2	0.0003	12	0.0008	5	0.18	0.06	0.40	0.10
3	0.0001	15	0.0011	3	0.16	0.12	0.25	0.08
4	0.0005	15	0.0009	7	0.24	0.05	0.45	0.05
5	0.0002	20	0.0005	4	0.08	0.09	0.35	0.15
6	0.0005	20	0.0002	7	0.17	0.07	0.55	0.10

Table 2. Parameters Of Subtasks

No of subtask j	Comp. complexity c_j (megaoperations)	Amount of output data O_j (megabytes)	Input data blocks needed B_j
1	1000	5	1,3
2	800	7	2
3	2500	12	1,4
4	1200	3	2,3,4
5	500	14	4
6	900	8	2,5
7	1500	10	2,4,5
8	600	2	1,5

Table 3. Parameters Of Input Data Blocks

No of data block	1	2	3	4	5
Amount of data (Mb)	22	12	7	10	6

Table 4. Data Security Constraints

No of SDTG b	Subtasks composing SDTG: ψ_δ	Maximal SDTG insecurity Y_δ^*
1	1,3,8	0.02
2	3,6	0.04
3	4	0.08

Table 5. Service Tariff Agreement

No of service time interval l	Θ_{l-1}^*, Θ_l^*	Service price w_l
1	0, 150	1 000
2	150, 300	800
3	300, 600	600
4	600, ∞	0

In the second case the service security is critical, whereas the service reliability is neglected: e_Y is considerable and e_R=0. The provider prefers to assign more subtasks to secure resources. For example the number of subtasks assigned to the most secure resource 5 (y_5=0.08) raises from 1 to 3. The improvement of the service security causes the provider's profits reduction.

In the third case both the service reliability and security are important. It is assumed that e_R=e_Y. The optimal solutions achieve a compromise balancing the reliability and security. That is, the provider increases the parallelization and assigns more subtasks to secure resources by the price of profit reduction.

Table 6. Task Partition And Distribution For R^*=0.96, Y_δ In Table 4 And Different Service Tariffs*

Tariff		Resources					
e_R	e_Y	1	2	3	4	5	6
Case 1:							
0	0	5,7	2,6	2,6	5,7	3	1,4,8
750	0	2	2	4,7	4,7	1,3,5,6,8	1,3,5,6,8
1500	0	-	2,4,7	2,4,7	2,4,7	1,3,5,6,8	1,3,5,6,8
Case 2:							
0	0	5,7	2,6	2,6	5,7	3	1,4,8
0	750	1,5,8	2,6	2,6	1,5,8	4,7	3
0	1 500	1,2	7,8	1,2	7,8	4,5,6	3
Case 3:							
0	0	5,7	2,6	2,6	5,7	3	1,4,8
700	700	1,5,8	2,6	2,6	1,5,8	4,7	3
1500	1500	5,8	5,8	3	3	1,2,4,6,7	1,2,4,6,7

Table 7. Parameters Of The Optimal Service Solutions For R^*=0.96, Y^*_δ From Table 4 And Different Service Tariffs

Tariff		Θmin	Θmax	P	$E(W)$	Vr	Vc	Vs	$R(\infty)$	Y_1	Y_2	Y_3
e_R	e_Y											
Case 1:												
0	0	149.6	217.3	571.1	748.7	67.82	23.05	86.73	0.771	0.014	0.025	0.17
750	0	289	299.5	468.3	694.5	85.8	26.78	113.7	0.913	0.236	0.236	0.362
1 500	0	289	302.7	456.8	723.0	101.2	28.79	136.3	0.945	0.236	0.236	0.477
Case 2:												
0	0	149.6	217.3	571.1	748.7	67.82	23.05	86.73	0.771 20	0.014	0.025	0.17
0	750	149.4	232	555.3	736.3	68.9	23.89	88.30	0.771 57	0.054	0.053	0.08
0	1 500	148.9	197.7	545.0	730.7	68.55	27.37	89.87	0.771 61	0.016	0.014	0.08
Case 3:												
0	0	149.6	217.3	571.1	748.7	67.82	23.05	86.73	0.771 2	0.014	0.025	0.17
700	700	149.4	232	424.1	605.2	68.9	23.89	88.30	0.771 6	0.054	0.053	0.08
1 500	1 500	282.9	292.5	322.9	558.0	86.93	31.16	117.1	0.913	0.022	0.086	0.236

5. CONCLUSIONS

Grid computing allows effective distribution of computational tasks among different resources presented in the grid. The resource management system (RMS) can divide service task into subtasks and send the subtasks to different resources for parallel execution, which leads to reduction of the service data security.

The service provider can charge different prices depending on the service time and/or the service insecurity in accordance with a fixed tariff. Given the limited reliability of the grid elements the service time is a random variable. For any given service task the probabilistic distribution of service time depends on task partition into execution blocks and their assignment to the available resources. The suggested optimization algorithm is aimed at achieving the greatest provider's profit based on service tariff depending on service time and data security level. The high computational efficiency of the proposed algorithm is achieved by using the universal generating function approach for evaluating the service time distribution.

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REFRENCES:

[1] D. Kaleeswaran, Y. Sobiya, P.R.Joe Dhanith, and R. Sivasenthil, "Novel job distribution architecture tool for grid computing", *Journal of Theoretical and Applied Information Technology*, Vol. 41, No. 2, July 2012, pp. 247-252.

[2] I. Foster, Y. Zhao, I. Raicu, and S.Y. Lu, "Cloud Computing and Grid Computing 360-Degree Compared", *GCE: 2008 Grid Computing Environments Workshop*. November 16, 2008, Austin, TX, pp. 60-69.

[3] Krauter, K., Buyya, R. and Maheswaran, M. A taxonomy and survey of grid resource management systems for distributed computing. Software - Practice and Experience, vol. 32, no. 2, pp. 135-164, 2002.

[4] M. Makhlouf, F. Messai, and H. Benalla, "Modeling and control of a single-phase grid connected photovoltaic system", *Journal of Theoretical and Applied Information Technology*, Vol. 37, No. 2, March 2012, pp. 289-296.

[5] England, D. and Weissman, J.B. A stochastic control model for the deployment of dynamic grid services. *The 5th IEEE/ACM International Workshop on Grid Computing*, pp. 192-199, 2004.

[6] Alhazmi O and Malaiya Y., Application of vulnerability discovery models to major operating systems. *IEEE Transactions on Reliability*, vol. 57, no. 1, pp. 14–22, 2008.

[7] Alhazmi O and Malaiya Y. Quantitative vulnerability assessment of systems software. *In Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 615–620, 2005.

[8] Tai A, Meyer J and Avizienis A. Performability enhancement of fault-tolerant software. *IEEE Transactions on Reliability*, vol. 42, no. 2, pp. 227–237, 1993.

[9] Meyer J. On evaluating the performability of degradable computing systems. *IEEE Transactions on Computers*, vol. 29, pp. 720–731, 1980.

[10] Ushakov, I. Optimal standby problems and a universal generating function, *Soviet Journal of Computer Systems Science*, vol. 25, pp. 79-82, 1987.

[11] Levitin G and Dai Y. Optimal service task partition and distribution in grid system with star topology. *Reliability Engineering and System Safety*, vol. 93, no. 1, pp. 152–159, 2008.

[12] Rubinovitz J. and Levitin G. Genetic algorithm for assembly line balancing. *Int. Journal of Production Economics*, vol. 42, pp. 343-354, 1995.

[13] Levitin G., Masal-Tov S. and Elmakis D. Genetic algorithm for open loop distribution system design. *Electr. Power Syst. Res.*, vol. 32, pp. 81-87, 1995.