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THE STRUCTURAL-FUNCTIONAL SYNTHESIS OF CLOUD SERVICE DELIVERY PLATFORM AFTER SERVICE AVAILABILITY AND PERFORMANCE CRITERIA

In this paper criteria and constraints are presented for synthesis of distributed service platforms based on the cloud service-oriented architecture such as availability and system performance index by several interconnected probabilistic problems solving. The method of synthesis has been proposed considering the type of service workload in statistical and analytical form for each integrated service that requires implementation within the service delivery platform, which is synthesized by structural matching of virtual machines using combination of elementary servicing components up to functionality into a best-of-breed solution.

Keywords: *SDP, structural-functional synthesis, cloud computing, cloud service delivery platform, distributed service platforms.*

Introduction

The structural-functional integrity of modern cloud networking paradigm is very important to build scalable and reliable commercial infrastructures using Service-Oriented Architecture (SOA). There are a lot of applications using this architectural concept to be effective in a concurrent world of e-business, e-commerce, personal communications and other activities [18, 19]. Despite it, mentioned networking concepts were widely appeared for very last years. Due to extreme complexity of design, and high commercial value of such network solutions we are intended to make an effort proposing a common analytical synthesis method for structural and functional parameters optimization within given restrictions for typical service delivery platforms (SDP).

Today cloud computing services are widely spreaded among market opportunities that making business more effective and scalable [19]. Most famous solutions were presented by Microsoft (Microsoft Azure), Google (Google Apps Engine), Amazon (Elastic CloudComputing, Simple Storage Service), IBM (Blue Cloud), Nimbus, Oracle and others. Besides large corporative clouds, a cloud computing services are provided by small companies too. There are free solutions also available at the marketplace, such as iCloud, Cloudo, FreeZoho, SalesForce etc. All these solutions are different by services offered, as SaaS (software as a service), as well as PaaS (platform as a service), and IaaS (infrastructure as a service), and over more HaaS (hardware as a service). Despite the variety of services (generally spoken XaaS), there are quite typical hardware and software facilities used as the basis of most of could systems. They are facilitating an operation of the system that built in accordance to SOA being realized as the set of virtualized service nodes or virtual machines, replicating them with scalability to support some sets of services flexibly and up to nomadic consumers' needs. Respectively, hardware and software facilities sometimes are working badly or unreliable because of imperfection or degradation with some probability. To minimize this probability and to decrease a cloud system restoration period, some principles applied, much of them are the principles that used for distributed data processing (reserving, re-distribution of calculating resources etc.). Such approaches are intended to hide partially from consumers the real situation with system availability and to make an illusion of the no-faulty operation. Besides that, the typical failures statistic at the cloud SOA is very interesting (see Tabl. 1) [11]. It shows us that existing approaches to the high-reliability (or more correct to be said high service availability) cloud systems design are not too effective.

Analyzing deeper, these statistics evidences that cloud system unavailability is not the single result of the failures. In the case of Microsoft Sidekick failure all the users' personal data were lost [11], that were restored soon, but not in full.

Despite the high level of the implementation of well-known solutions for servicing systems availability increasing, cloud-systems are still analyzing for systematic bottlenecks in SOA, to improve system reliability, services availability level, system performance index [13, 14]. So the actuality of these issues is very high.

Hereinafter we use term "structural parameter" to designate a number of specific elementary servicing components, well organized after virtual machines' structure, there are no clear common topological or network patterns could be formalized to characterize the "cloud" in the terms of traditional networking.

Table 1

The typical failure statistics of cloud-systems

№	Service provider name	Services affected	Date	Unavailability period
1	Google	Gmail, Google Apps Engine	24.02.2009	2,5 hrs
2	Google	Google Search	31.01.2009	40 min
3	Google	Google Gmail	9.03.2009	22 hrs
4	Google	Google Network	14.05.2009	`
5	Amazon	Amazon Elastic Cloud Computing	11.06.2009	7 hrs
6	Amazon	Amazon Elastic Cloud Computing	9.12.2009	5 hrs
7	Amazon	Amazon Simple Storage Service	15.02.2008	2 hrs
8	Amazon	Amazon Elastic Cloud Computing	21.04.2011	27 hrs
9	Microsoft	Microsoft Azure	13-14.03.2008	22 hrs
10	Microsoft	Microsoft Hotmail	12.03.2009	5 hrs
11	Microsoft	Microsoft Sidekick	4.10.2009	144 hrs
12	Flexiant	FlexiScale	31.10.2008	18 hrs

Generally, virtual machines (VM) topology is dynamic, services offered and demanded set is dynamic too. VM are migrating and replicating elementary services in accordance to the nomadic consumers' needs. This is to postulate that cloud SOA accepts a "heap" of migrating resources inside cloud system, which actually is extremely distributed object, being a concrete service delivery platform (SDP) realization. We could separate some specific groups of these servicing components used to organize complex orchestration process while a service application is preparing to be used by customers of SDP. The classification of servicing components as a threads which are realizing by VM is conforming to the Amdahl's Law terms could be used for this purpose [17]. Therefore, we could separate hypervisors and other sequentially operating elementary servicing components of service application (α) to the one group, and elementary servicing components (ESC) are operating in parallel to another one ($n-\alpha$) see Fig. 1. Hereinafter n is the total number of ESC.

Thus, a problem of optimal structural synthesis could be simplified to the task of optimal ESC number choice for each defined group within their combination to realize common cloud SOA as effectively functionally embedded SDP. Unfortunately, the main difficulties corresponding to solution of structural-functional synthesis problem are injected first of all by the lack of knowledge about probabilistic processes of traffic serving into the servicing application structure of SDP under workload, that induced by service of some type [14 – 16]. Functional properties of our service should be given in stochastic terms and should be directly addressed to the properties of served workload traffic.

A self-similarity Hurst parameter of the workload traffic could be used to characterize its statistical properties, and, correspondingly, to define this statistic for specific traffic types (such as VoIP, VoD, IPTV Multicast, Web data etc.). Hereinafter we mean that "functional parameter" for respective service was previously defined statistically as correspondently calculated Hurst parameter for respective workload traffic type to be served by cloud SOA.

Therefore, for each synthesized realization of cloud architecture service availability should be represented and calculated for each functional service offered by service delivery platform as well as structural performance index for each structural combination of ESC. Both of mentioned indexes are chosen as criteria for optimal SDP structural and functional synthesis.

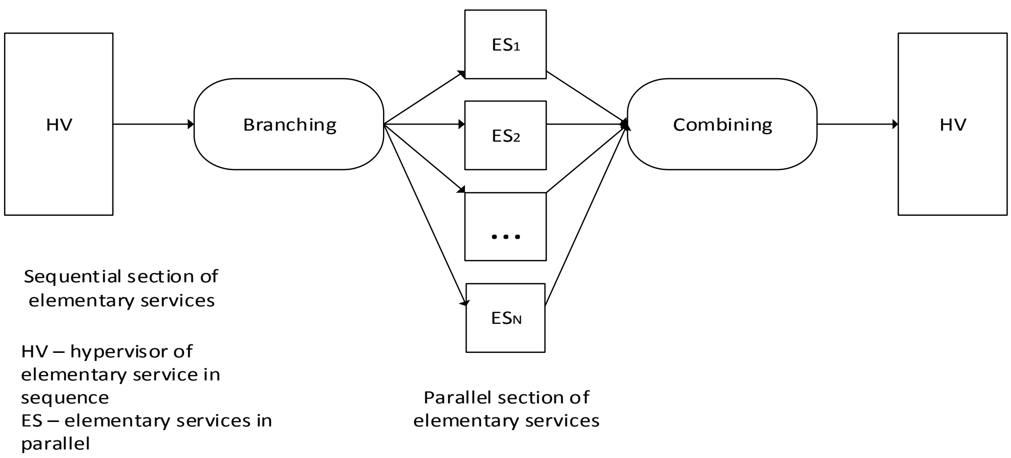

Fig. 1. Parallel and sequential sections of elementary services virtual structure in cloud SOA

In the next section we tried to represent these criteria in pure analytic mathematical form. After that, we define all the parameters used in the criteria expressions to simplify the task of optimal synthesis process realization by numeric simulation. This work is written with assumption taken that design of the transport layer of SDP is provided for optimal service flows distribution at its distributed flexible realization [15].

The synthesis criteria and parameters

As it is known, the simplest network structure (topology) is undirected (oriented) graph G with a set of vertices V and set of edges (arcs) E, which correspond to nodes and lines. The simplest model of structural reliability of the information service system, or, more precisely, its availability - is random graph (G; p) with p = {p (ε); ε ∈ E}. It could be characterized by independent removal of edges of G (arcs) ε ∈ E with probability q (ε) = 1 - p (ε).

In a service system, the availability will be characterized as survivability of a set of VM, which implementing a given service or system's ability to quickly and easily recover the normal operating mode. However, this concept could be described as the ability of the system to perform its operation during a long period of time with maximal efficience, i.e., reliably. The concept of service availabilty and survivability in the theory of complex systems (e.g., cloud networks) are interrelated.

The most important component of cloud system reliability is the availability property which describes the ability of the server system to survive continuously in the given conditions and during the given interval of operation which is calculated through survivability of distributed service implementation of VM set, which is used for implementing various combinations of ESC.

An ESC coalescing forms some integrated service or application which is directly realizing it.

The properties of ESC combination are affecting the service availability and overall system performance index.

To assess this parameter in the cloud system, it should be clearly understood that the topology of the network is dynamic and constantly changes. In our model, we evaluate the survivability of structures in terms of the probability of connection of two segments in the next moment, i.e., there will be at least one edge.

This edge is a "key link" to connect these segments. On the other hand, there must be a workable ESC, which is not overloaded and is able to process the given stream of requests. These probabilities are affected by the probability of failure of a certain path in the middle segment of the server system (i.e., between subscribers in the middle of each segment there is at least one route) and each VM, which is implemented by the ESC at any given moment of time, and this mean that they are also depended on the probability of requests blocking at ESC in the middle of each segment.

In [1] under information systems vitality is meant the ability of systems to perform their basic functions (at least within tolerable loss of quality of service) under the impact of outer factors. This definition is close in meaning to the definition [2]. In [3] this concept is defined as a property of the object that expressed to be an ability to perform a given task under the deleterious effects on the entire object or its individual components, keeping within acceptable limits an operational performance. These definitions pay attention to such points. First one is the vitality should be considered as an intrinsic property of the system as it is not dependent on operating conditions that arise at any given moment of time. It posesses this property all the time and to some extent the property could occur under normal operating conditions, where there are failures that are caused by manufacturing defects, degradation, maintaining etc. But in full the survivability is appeared under the large external influences that are not expected for normal operation. And it is difficult to forecast them because they create extreme operating conditions. Second one is the system supports not all the functions that it should perform during normal operation, but only the basic functions and sometimes with possible reduction in QoS. This means that the strategy of the system with increasing a severity of adverse effects should be changed.

In the studies about survivability and availability, we could identify a number of areas (approaches) and therefore some types of analysis: game-theoretical [4, 5], probabilistic [6], deterministic [7, 8], graph [9, 10]. Probabilistic and deterministic approaches are the most developed for technical purposes. The main ideas of these models were outlined in [10].

The probabilistic methods of survivability investigation are based on assumption of an uniform distribution law of adverse (harmful) effects (HE) within the studied system or under assumption about the same amount of damages arising from any place while implementating a single system HE.

Deterministic methods of survivability investigation are based on a matching of specific types of damaging factors HE and resistance of system elements and the system as a whole. In this direction, there are two approaches: static and dynamic. The essence of the static approach is being set by object’s weak region and by the level of damaging factors, then the list of items that might be damaged is determined, and using the logical functions of functionality is applied, as a result the level of the system operation quality is determined. A dynamic approach is based on the use of simulation models, including dynamic models: the emergence and development of HE; development of HE factors that affect the state of the elements of the object; object operaring in terms of structural and parametric changes induced by damaging factors and by countermeasures to HE.

Graph models are characterized by simplicity and high redundancy and traditionaly used in the study of structural survivability introducing the concept of "destruction". The system that is represented by a graph can be considered as destroyed, if after removing of the vertice the graph resulted that satisfies to one or more of the following conditions:

– Graph contains at least two components.

– There is no directed paths for a given set of vertices.

– The number of vertices in the largest component of G is less than some given number.

– The shortest way is longer than certain given value.

Accordingly, a system is considered as survivable, and a service system is considered as available in the absence of these conditions, being formed on relevant edges represented by ESC that are also not overloaded.

A task of optimal parametric synthesis of cloud SDP realization could be solved by optimal choice of the designed system parameters indexes for each declared complex service; for simplicity purposes we define that $x_{opt} = (\alpha, n, H)$ should maximize the following equations used to define synthesis criteria:

$$x_{opt} = \arg\max P_A \left\{ X\left(x_{opt}, t\right) \in D_x,\ \forall t \in [0,T] \right\}, \\ x_{opt} = \arg\max_{x_{opt} \in D_x} S_p\left(x_{opt}\right). \quad (1)$$

Here $X\left(x_{opt}, t\right)$ is s probabilistic process of parameters x_{opt} changing, $P_A(\bullet)$ is a service availability stochastic functional and $S_p\left(x_{opt}\right)$ is a structural performance functional. Here D_x is a tolerance region for x_{opt} parameters, T is exploration time for current SDP realization. Let us define the tolerance region:

$$D_x = \left\{ x \in R^3 : P_{A\min} \le P_A(x) \le 1 \right\}. \quad (2)$$

Here $P_{A\min}$ is minimal acceptable service availability within designed SDP.

The solution for task (1) is based on the analysis of the interrelations of the service availability and ESC parameters, as well as workload traffic statistical parameters, which represented by Hurst aggregative parameter. 1st and 2nd statistical moments for workload traffic served by respective service are also needed to examine all necessary stochastic characteristics. These parameters could be easily obtained after statistical simulation of the workflow intensity with necessary H parameter [16].

A set of internal parameters $x_{opt} = (\alpha, n, H)$ could be represented as a point inside R^3 cube, and the space of allowed x_{opt} parameters is limited by D_x tolerance region.

Criteria calculation

Given internal SDP parameters we could determine [10, P.100-101]:

$$P_A(\bullet) = \frac{1}{N_0} \sum_{i=1}^{N_0} P_i(x,t)\left(N_0 - i\right), \quad (3)$$

where $N_0 = N(N-1)/2$, N is a number of SDP service nodes with organized VM, that aggregating respective ESCs. There is no trivial solution was found and the common task was spitted to the parts using additive survivability definition [10]:

$$P_i(x,t) = \sum_{i=0}^{\alpha} G_i^{E2}(x,t) + \\ + \sum_{i=\alpha+1}^{n} G_i^{E1}(x,t) + \sum_{i=n+1}^{N} G_i^{P}(x,t), \quad (4)$$

respectively using [20] and Erlang process of i-th order definition:

$$G_i^{E1}(x,t) = \frac{\left(i\Lambda_i^{E1}(x)\right)^i}{(i-1)!} t^{i-1} e^{-i\Lambda_i^{E1}(x)t}, \quad (5)$$

respectively $\Lambda_i^{E1}(x) = \frac{h_1(x)\pi_1}{i(n-\alpha)}$ and $h_1 = \lambda p_1(x)$, hereinafter π_1 is an average physical availability of VM at each parallelized by ESC combination SDP service node. Let us define using Norros equation transformations [16]:

$$p_1(x) = \exp\left(\begin{array}{c} -(1-H)^{2H} H^{-2H} (H-1)^{-2} \times \\ \times \left(\begin{array}{c} 2^{-\frac{1}{2H}} \left(c_v (n-\alpha)^{\frac{1}{2}} \right)^{-H/2} B^{\frac{1}{H}-1} \times \\ \times \left(C - \lambda/(n-\alpha)\right) \left(\frac{\lambda}{n-\alpha} \right)^{-H/2} \end{array} \right)^{2H} \end{array} \right),$$

here B is a buffer utilization ratio at the moment t, H- is the Hurst parameter of respective traffic type, that applicable for examined complex service, C is the average throughput capacity of the ESC, λ is a traffic intensity, c_v is a coefficient of variation of the incoming workload traffic, both indexes are for examined complex service. Consequently using Erlang process of i-th order definition:

$$G_i^{E2}(x,t) = \frac{\left(i\Lambda_i^{E2}(x)\right)^i}{(i-1)!} t^{i-1} e^{-i\Lambda_i^{E2}(x)t}, \quad (6)$$

where $\Lambda_i^{E2}(x) = \frac{h_2(x)\pi_2}{i}$ and $h_2 = \lambda p_2(x)$, hereinafter π_2 is an average physical availability of VM at each sequential by ESC combination SDP service node. Let us define using Norros equation transformations [16]:

$$p_2(x) = \exp\left(\begin{array}{c} -(1-H)^{2H} H^{-2H} (H-1)^{-2} \times \\ \times \left(2^{-\frac{1}{2H}} c_v^{-H/2} B^{\frac{1}{H}-1} (C-\lambda)\lambda^{-H/2} \right)^{2H} \end{array} \right);$$

and respectively using Poisson process definition [20]:

$$G_i^P(x,t) = \frac{(\pi_3 \lambda p_2(x))^i t^i}{i!} e^{-\pi_3 \lambda p_2(x) t}, \qquad (7)$$

where π_3 is an average physical availability of VM at each transport SDP service node.

Using (4) – (7) we define the statistical distribution for ESC combination and respectively service availability criterion (3) calculation on the each synthesized VM structure of cloud SDP. Using the same set $x_{opt} = (\alpha, n, H)$ that was used in (3) we simultaneously define structural performance by the second synthesis criterion after Amdahl's Law, see Fig. 2 [17]:

$$S_p(x) = \frac{1}{\alpha + (1-\alpha)/n}. \qquad (8)$$

We could define structural performance index using (8) for given ESC structural combination, thus maximization task (1) should be consistently solved in iterations.

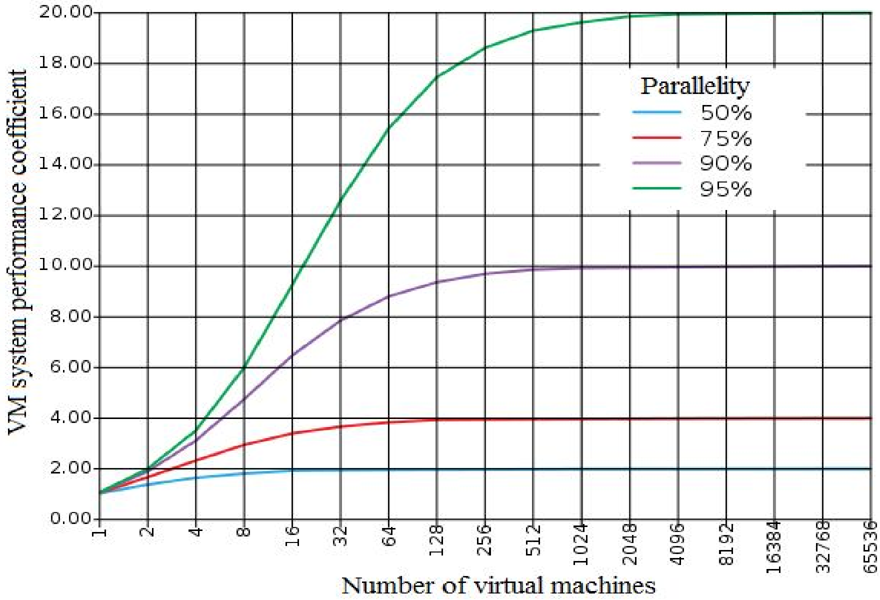

Fig. 2. VM systems' performance coefficient after Amdahl's Law [17]

Conclusions

In this paper criteria and constraints are presented for synthesis of distributed service platforms based on the cloud service-oriented architecture such as availability and system performance index by several interconnected probabilistic problems solving. The method of synthesis has been proposed considering the type of service workload in statistical and analytical form for each integrated service that requires implementation within the service delivery platform, which is synthesized by structural matching of virtual machines using combination of elementary servicing components up to functionality into a best-of-breed solution.

As a result of restrictions from Amdahl's Law the necessity of cloud-networks clustering arises after basic service components of ESC, which makes it possible to break the complex dynamic network into separate segments that simplifies access to the resources of virtual machines and, in general, to the "clouds" and respectively simplifies complex topological structure, enhancing the overall system performance.

It can be concluded that the higher number of cluster elements the faster cluster nodes' incoherence probability grows, the clusters becomes more sparse, in addition the parameters of the route estimating by the criterion of minimum proximity takes longer.

This may result in some delays in service provision. In overall, proposed approaches could mathematically justified and algorithmically describe the process of structural and functional synthesis of efficient distributed service platforms, which under process of their configuring and exploitation provides an opportunity to act on the dynamic environment in terms of comprehensive services range and nomadic users' workload pulsing.

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СТРУКТУРНО-ФУНКЦІОНАЛЬНИЙ СИНТЕЗ РОЗПОДІЛЕНИХ СЕРВІСНИХ CLOUD ПЛАТФОРМ ЗА КРИТЕРІЯМИ ДОСТУПНОСТІ СЕРВІСІВ ТА ПРОДУКТИВНОСТІ СИСТЕМИ

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У роботі запропоновано критерії та обмеження для синтезу розподілених сервісних платформ на основі хмаринкових сервісно-орієнтованих архітектур за сервісною доступністю та показником системної продуктивності шляхом розв'язання кількох взаємопов'язаних імовірнісних задач. Запропонований метод синтезу дозволяє враховувати тип сервісного навантаження, поданий у статистико-аналітичній формі для кожного комплексного сервісу, який потребує реалізації в рамках сервісної платформи, що синтезується, шляхом підбору структури її віртуальних машин комбінацією елементарних сервісних компонентів згідно заданої функціональності найбільш оптимальним чином.

Ключові слова: *SDP, структурно-функціональний синтез, хмарні обчислення, розподілені сервісно-орієнтовані платформи.*

СТРУКТУРНО-ФУНКЦИОНАЛЬНЫЙ СИНТЕЗ РАСПРЕДЕЛЕННЫХ СЕРВИСНЫХ CLOUD ПЛАТФОРМ ПО КРИТЕРИЯМ ДОСТУПНОСТИ СЕРВИСОВ И ПРОИЗВОДИТЕЛЬНОСТИ СИСТЕМЫ

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В работе предложены критерии и ограничения для синтеза распределенных сервисных платформ на основе облачных сервисно-ориентированных архитектур с учетом сервисной доступности и показателя системной производительности путем решения нескольких взаимосвязанных вероятностных задач. Предложенный метод синтеза позволяет учитывать тип сервисной нагрузки, представленный в статистико-аналитической форме для каждого комплексного сервиса, который требует реализации в рамках сервисной платформы, синтезируемой путем подбора структуры ее виртуальных машин комбинацией элементарных сервисных компонентов согласно заданной функциональности наиболее оптимальным образом.

Ключевые слова: *SDP, структурно-функциональный синтез, облачные вычисления, распределенные сервисно-ориентированные платформы.*