A New Method to Build Services in Equipment Grid

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Abstract

Services in grid are stateful and transient web services, which can be invoked by clients, and are considered to be the mainstream of future internet. Equipment grid refers to the grid that connects distributed equipments together and provides transparent service invocation and coordination. A new approach to build services in equipment grid is provided as follows, a directed graph model for services is developed first by creating several service providers and directed edges among every pair of them, then increase the number of service providers and random connections among them. When the size of service network grows up, new service providers are no longer randomly connected to previous providers but choose those with high incoming degree. This method differs from former methods of building small world complex networks in its evolution process and imitation of real world scenarios. This approach is analyzed through simulation on our equipment grid testbed and has characters of complex networks such as small world and scale free. Some metrics are analyzed such as accessible probability of grid services building through this way versus dynamic probability when service providers dynamically quit grid system and stop to provide their services. Experiment results show the effectiveness of this new method.

Keywords:
Service Oriented Architecture, Grid, Equipment grid, Small world networks, Directed graph

1. Introduction

Service Oriented Architecture (SOA) has attracted many research interests recently. It is a trend to solve many difficult real world problems. The definition of Web Service and related information is provided in [1]. Conception of SOA and its applications are introduced in [2] and [3], as well as some limitations. For example, Web Service can not provide transitory and stateful services, which are confirmed to be important in some application scenarios. Grid service is developed on Web Service and can provide transit and stateful services. The reason why stateful services are necessary is that Virtual Organizations in grid are organized and disbanded dynamically. The resources in them generally provide transient services.

Grid is a technology aiming at connecting resources together for share and collaboration in form of grid services. The idea of grid originated from the 1960s. It suggested connections of mainframes to provide more powerful computing ability. Grid was well known to the world when [4], in which basic conceptions and key ideas of grid was introduced, published. Grid is expected to be an infrastructure like power grid system. The concept of grid and some grid projects are introduced in [5] and [6]. The sandglass architecture of grid is proposed in [7]. This architecture is a protocol based architecture and consists of five levels. The tool (Globus Toolkit 2) that support sandglass architecture was published and was used to develop grid projects. But in practice, sandglass architecture is not compatible with current industry network protocols. Another version of grid architecture, Open Grid Service Architecture (OGSA), is introduced in [8]. The services based on OGSA are called grid services. Grid service is a kind of transient stateful Web Service that supports reliable and secure service invocation, lifetime management, notification, policy management, credential management and virtualization. Current version of toolkit to develop grid service, Globus Toolkit 4, was published in 2005.

Grid has achieved great success. There are many successful grid project examples, like Science Grid [9], EUROGRID [10] and Data Grid [11]. But there is little literature focus on theoretical analysis of accessibility to grid service, although Universal Description and Integration (UDDI) provides some basic functions like publishing and locating information about Web

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Services. When UDDI servers are under attack, many of web services will not be accessible.

Equipment grid is an infrastructure that connecting geographically distributed equipments together and provides transparent service invocation by grid technologies. The idea of equipment grid was proposed in [18], which provides an abstraction of equipments and publishes their functionalities in form of grid service. Architecture of equipment grid and its possible applications are also provided. Equipment grid service chain sharing method is presented in [19]. In [20] equipment pool model is proposed to model equipment grid. In this model, there are physical equipments, equipment pools and equipment pool alliance respectively. As shown in Figure 1.

In Figure 1, equipment pools consist of same kind of equipments. Different kinds of equipment pools constitute an equipment pool alliance. Geographically distributed equipments are connected with high speed networks and agglutinated with specifically designed middleware software.

The following 8 steps constitute a full service invoking process in equipment grid. When a user wants to conduct an experiment, he submits it to equipment pool alliance in Step 1. Pool alliance will check whether it has the required resources needed to fulfill this experiment. If not all resources needed are available, pool alliance will reply the user with refusal information in Step 2. Otherwise it accepts this request. Equipment pool alliance analyzes this experiment and distributes it to related equipment pool or pools in Step 3. All related pools will schedule suitable resources to run this experiment in Step 4. In Step 5, selected resources return results to their pools after they finished their jobs. Equipment pools send results to pool alliance in Step 6. Pool alliance composes all results received and gives a final result to user in Step 7. In Step 8, user feed back some useful information, like his appraisal to this experiment and other suggestions etc, about the experiment.

In [21] π-Calculus is imported into equipment grid to test validity of equipment grid service chain model. Resource scheduling schemes in equipment grid is discussed in [22] and [23] and simulation is provided in [24]. In engineering practices, research work in [25] connected medical equipments and realized remote diagnosis on certain diseases. Research work about remote manipulation of distributed equipments is introduced in [26].

These former research efforts make such an assumption that all grid services can be discovered and accessed easily. Current way to realize such assumption is to publish new grid services on UDDI, a centralized information center. But when UDDI paralyzed, the whole system will not work properly.

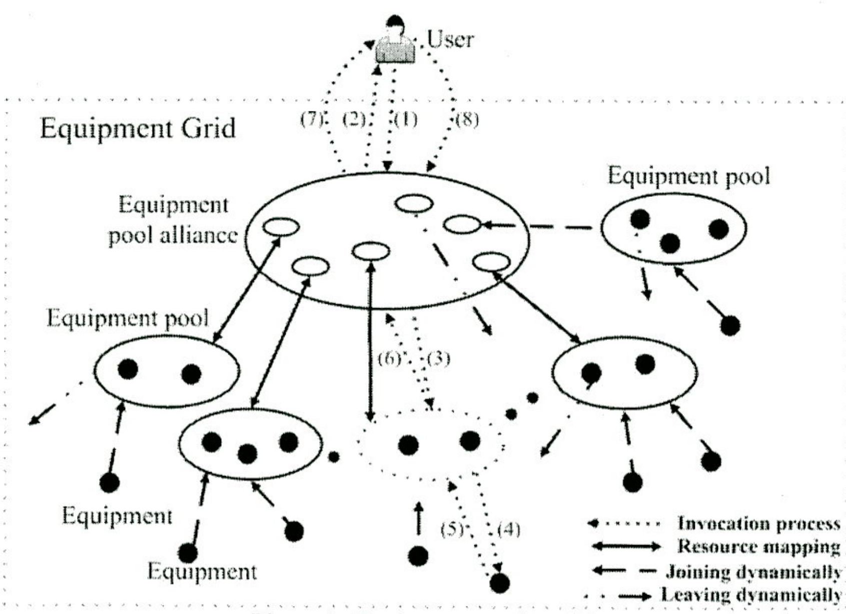

Figure 1. Equipment pool model

How to provide easy access to services in equipment grid is thus of vital importance, for there are so many services in grid and centralized information center is obviously inappropriate. An efficient service searching algorithm will facilitate easy access to grid services. This paper proposed an algorithm that building distributed relationship among grid services. Simulation demonstrates effectiveness of this algorithm.

This paper is organized as follows. In Section 2, we discuss grid service and key issues about it. In Section 3, we present an algorithm to build up grid services. Simulation of this algorithm is demonstrated on our equipment grid testbed in Section 4. We analyse simulation results and identifying issues that need further investigation in Section 5.

2. Backgrounds

Service invoking process in grid is as follows. A client sends a service request to a scheduler. In Globus Toolkit 4, Grid Resource Information Service (GRIS) and Grid Index Information Service (GIIS) act as scheduler. The scheduler goes to find service providers that can provide related service needed. After negotiation, the Universal Resource Identifier (URI) of that service is returned. The client invokes the service with input data and other necessary information.

While there are many service providers in grid system, a suitable way to describe such system is directed graph, which is an active research field in computer science, physics and social science. In a directed graph, vertices represent service providers providing some kind of services. In this work all services are modeled as non distinctive abstract services and all service providers can be clients of other services. The directed edges represent the ability to access services with edges pointed to the service providers.

The above directed graph model is a high level and abstract model for grid service. Our research focus is on connectivity of the graph, which means accessibility of certain service in grid. This model takes no account of some detailed processes like how to discover a suitable service provider, security issues, cost of invoking services and related provenance.

When the number of services increased, the directed graph becomes complex networks.

The complex networks have been under research for a long time by different groups of researchers range from physicists, computer scientists to social scholars. Current research work on complex networks focus on topology, shortest path between any two vertices, graph traversal and statistical characteristics of complex system like clustering and degree distribution. Many real world phenomena can be classified into complex networks problems. A social instance is that a group of people as vertices with some kind of interaction between them as edges. These edges can represent friendship between individuals, business relationship among families. Social networks, information networks, technology networks and biological networks can also be considered to be complex network.

Early model to describe complex networks was random graphs. In random graphs, given N vertices and P, the probability of any two vertices that have an edge between them, random graph theory can provide methods to acquire some statistic information like clustering coefficient and degree distribution. The degree distribution in random graph is a Poisson like distribution. Another famous model of complex networks is small world model proposed in [12], which shows a random edge between two vertices with long distance will shorten whole average path length in an undirected graph. The small world model explained the phenomenon of six separations, which means any two persons, can find that they are linked by almost six other people. This phenomenon exists in a large variety of fields. It was found that degree distribution in some real networks do not similar to Poisson distribution as in random networks but power law distribution [13]. Power law distribution is explained in [13] as result of two factors in an undirected graph, size incensement and purposely connections with high degree vertices instead of randomly. The directed graph model of internet was introduced in [14] and through experiments on internet found that directed model of real internet had a longer average path length than undirected graph. Some reviews on developments and achievements in complex networks were introduced in [15], [16] and [17].

Compared with former works on complex networks, grid services are more dynamic and their major concerns lie in accessibility of services. When represented by directed graph model, the major concern of equipment grid is the connectivity of the graph. The algorithm introduced below will build a highly distributed connected equipment grid system. The relationships about graph size, dynamic probability of grid services versus probabilities of service accessibility are discussed.

3. Network evolution algorithm

The following algorithm introduced consists of two steps, which are free competition phase and preferential phase. The first step is free competition phase, in which new vertex connects with old vertices randomly. The second step is preferential phase, in which new vertex connects part of its outgoing edges more preferably to vertices with high incoming degree, and part of its edges to the rest vertices randomly. In this algorithm we assume that every service provider provide service to others and at the same time can be client of other services. Reflected in directed graph, this means each vertex has to point to other vertices and be pointed from others. These two steps are used to build model of grid services as well as many real world applications. In the first step, the position of each vertex is equal and they compete freely. While in the second step, the winner with more incoming edges will attract more connections.

***Algorithm*:**

1) Given m_0 vertices surrounding as a circle, shown in figure 2. Each vertex points to and be pointed by its two nearest neighbors. There is $2m_0$ edges altogether.

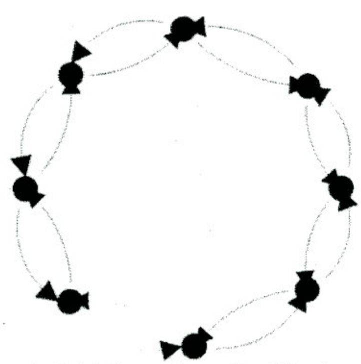

Figure 2. Initial topology for this algorithm

2) Create M vertices in turn. Every new vertex has a probability p_1 points to every existing vertex and a probability p_2 be pointed by every existing vertex. To ensure connectivity of the graph when graph is in its initial phase, an additional incoming edge from a randomly selected vertex and an outgoing edge to a randomly selected vertex should be added to new vertex. Suppose every vertex is numbered according to its order into the system, we can get the following equations.

In equation (1), $E(x_i^{in})$ means expected value of the number of edges pointed to the *i*th vertex x_i, and $E(x_i^{out})$ in equation (2) means expected value of number of edges pointed from the *i*th vertex. This step is known as phase of free competition.

In equation (1), the upper part means the expected value of vertex in the range $[0, m_0]$. Each vertex is pointed by its two nearest neighbors, so the number of incoming edges is 2. When the later M vertices join into the system, the expected value becomes the upper part. The lower part represents expected value of incoming edges pointing to the later M vertices. It is the same for equation (2).

3) When any new vertex joins into the system, randomly select a number, ξ_0, between 1 and n_0 and points these ξ_0 edges to $M+m_0$ vertices previously formed. The ξ_0 edges are pointed to $M+m_0$ vertices with probability proportional to their incoming degree, which is the number of incoming edges. This means a selected number of edges will be pointed from the new vertex to $M+m_0$ vertices according to equation (3).

Then randomly select a number, ξ_1, between 1 and n_1, point them to the rest of existing vertices. Incoming edges of the new vertex are selected randomly from all existing vertices with a selected number, ξ_2, between 1 and n_2. The above parameters, n_0, n_1 and n_2 are constant numbers and can be adjusted by users. This step is the process of preferential phase. Vertices with more incoming edges have more chances to attract more incoming edges.

In this step, the number of incoming and outgoing edges is independent of system size and only depends on n_0, n_1 and n_2. This is true in real scenarios, because it is impossible for new vertex to know the size of system. When a new service provider joins in grid system, he shares his resources to those he trusts and invokes services he knows (more incoming edges in directed graph has more chances to be known) or by some other means (randomly selected outgoing edges in directed graph) while taking no account of size of the system he is in.

After this step, we can calculate incoming degree ($x_i^{in'}$) and outgoing degree ($x_i^{out'}$) of each vertex, as shown in equation (4) and (5).

In equations (4) and (5), N means the number of vertices be added into system in step 3. x_i^{in} and x_i^{out} represent incoming degree and outgoing degree from step 2 with expected values shown in equation (1) and (2).

Since in (4) and (5), x_i^{in} and ξ_0 are independent, $\sum_{i=0}^{M+m_0} x_i^{in}$ and $\sum_{i=0}^{M+m_0} x_i^{out}$ are constants determined by M, m_0, p_1 and p_2. So we have the following equation (6) and (7).

Because x_i^{in} and ξ_0 are independent between each other, expected values of (4) and (5) can be shown in (8) and (9).

The expected values of ξ_0, ξ_1 and ξ_2 are $(1+n_0)/2$, $(1+n_1)/2$ and $(1+n_2)/2$, respectively. Combining equation (1) into (8) and (9), we have equations (10) and (11), which depict degree distribution of this algorithm.

$$E(x_i^{in}) = \begin{cases} 2 + \sum_{k=0}^{M} \frac{1+p_1(m_0+k)}{m_0+k} & (i \in [0, m_0]) \\ 1+(i-1)p_2 + \sum_{k=i-m_0}^{M} \frac{1+p_1(m_0+k)}{m_0+k} & (i \in (m_0, m_0+M]) \end{cases} \tag{1}$$

$$E(x_i^{out}) = \begin{cases} 2 + \sum_{k=0}^{M} \frac{1+p_2(m_0+k)}{m_0+k} & (i \in [0, m_0]) \\ 1+(i-1)p_1 + \sum_{k=i-m_0}^{M} \frac{1+p_2(m_0+k)}{m_0+k} & (i \in (m_0, m_0+M]) \end{cases} \tag{2}$$

$$x_j^{in} \Big/ \sum_{j=0}^{M+m_0} x_j^{in} \tag{3}$$

$$x_i^{in'} = \begin{cases} x_i^{in} + \frac{x_i^{in}}{\sum_{i=0}^{M+m_0} x_i^{in}} \xi_0 + \frac{1}{M+m_0+N}\xi_1 & i \in [0, M+m_0] \\ \frac{1}{M+m_0+N}\xi_1 & i \in (M+m_0, M+m_0+N] \end{cases} \tag{4}$$

$$x_i^{out'} = \begin{cases} x_i^{out} + \frac{1}{M+m_0+N}\xi_2 & i \in [0, M+m_0] \\ \frac{1}{M+m_0+N}\xi_2 & i \in (M+m_0, M+m_0+N] \end{cases} \tag{5}$$

$$E\left(\sum_{i=0}^{M+m_0} x_i^{in}\right) = \sum_{i=0}^{M+m_0} E(x_i^{in}) = M + 2m_0 + 2Mm_0p_1 + \frac{M+2m_0-1}{2}p_2M + \frac{p_1}{4}(M+m_0)(M+2m_0+2) + m_0\sum_{k=0}^{M}\frac{1}{m_0+k} + \sum_{i=m_0+1}^{M+m_0}\sum_{k=i}^{M+m_0}\frac{1}{k} \tag{6}$$

$$E\left(\sum_{i=0}^{M+m_0} x_i^{out}\right) = \sum_{i=0}^{M+m_0} E(x_i^{out}) = M + 2m_0 + 2Mm_0 p_2 + \frac{M+2m_0-1}{2} p_1 M + \frac{p_2}{4}(M+m_0)(M+2m_0+2) + m_0 \sum_{k=0}^{M} \frac{1}{m_0+k} + \sum_{i=m_0+1}^{M+m_0} \sum_{k=i}^{M+m_0} \frac{1}{k} \tag{7}$$

$$E\left[x_i^{in'}\right] = \begin{cases} E\left[x_i^{in}\right] + \dfrac{E\left[x_i^{in}\right]}{\sum_{i=0}^{M+m_0} E\left[x_i^{in}\right]} E\left[\xi_0\right] + \dfrac{1}{M+m_0+N} E\left[\xi_1\right] \\ (i \in [0, M+m_0]) \\ \dfrac{1}{M+m_0+N} E\left[\xi_1\right] \\ (i \in (M+m_0, M+m_0+N]) \end{cases} \tag{8}$$

$$E\left[x_i^{out'}\right] = \begin{cases} E\left[x_i^{out}\right] + \dfrac{1}{M+m_0+N} E\left[\xi_2\right] \\ (i \in [0, M+m_0]) \\ \dfrac{1}{M+m_0+N} E\left[\xi_2\right] \\ (i \in (M+m_0, M+m_0+N]) \end{cases} \tag{9}$$

$$E\left[x_i^{in'}\right] = \begin{cases} \left(2 + \sum_{k=0}^{M} \dfrac{1+p_1(m_0+k)}{m_0+k}\right)\left(1 + \dfrac{1+n_0}{2\sum_{i=0}^{M+m_0} E\left[x_i^{in}\right]}\right) \\ + \dfrac{1+n_1}{2(M+m_0+N)} \qquad (i \in [0, m_0]) \\ \left(1 + (i-1)p_2 + \sum_{k=i-m_0}^{M} \dfrac{1+p_1(m_0+k)}{m_0+k}\right)\left(1 + \dfrac{1+n_0}{2\sum_{i=0}^{M+m_0} E\left[x_i^{in}\right]}\right) \\ + \dfrac{1+n_1}{2(M+m_0+N)} \qquad (i \in (m_0, M+m_0]) \\ \dfrac{1+n_1}{2(M+m_0+N)} \qquad (i \in (M+m_0, M+m_0+N]) \end{cases} \tag{10}$$

$$E\left[x_i^{out'}\right]=\begin{cases}2+\sum_{k=0}^{M}\frac{1+p_1(m_0+k)}{m_0+k}+\frac{1+n_1}{2(M+m_0+N)} \\ (i\in[0,m_0]) \\ 1+(i-1)p_1+\sum_{k=i-m_0}^{M}\frac{1+p_2(m_0+k)}{m_0+k} \\ +\frac{1+n_2}{2(M+m_0+N)} \qquad (i\in(m_0,M+m_0]) \\ \frac{1+n_2}{2(M+m_0+N)} \\ (i\in(M+m_0,M+m_0+N]) \end{cases} \tag{11}$$

From (10) and (11) that once parameters like p_1, p_2, n_0, n_1, n_2, m_0, M, N are determined, the distribution of edges can be roughly estimated.

From this algorithm, we can find that from any of the service provider, you can invoke any services available on grid system when there is no services fluctuation dynamically in grid system.

4. Simulation results

The equipment grid testbed is developed using Java Server Pages (JSP) and JavaScript (JS), with Web server Tomcat, service container Axis and database MYSQL. Services are deployed on several computers with CPU 2.4GHz and 1G memory.

According to the algorithm proposed in Section 3, we deploy services on our equipment grid testbed by assign related parameters in three groups below, as shown in table 1. Group 1 has more edges than Group 2 and Group 3. Group 3 has the least edges of these three groups.

Figure 3 is incoming degree distribution with parameters set by above three groups and figure 4 shows outgoing degree distribution.

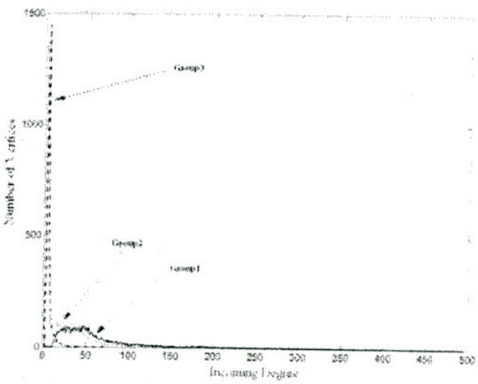

Figure 3. Incoming degree distribution

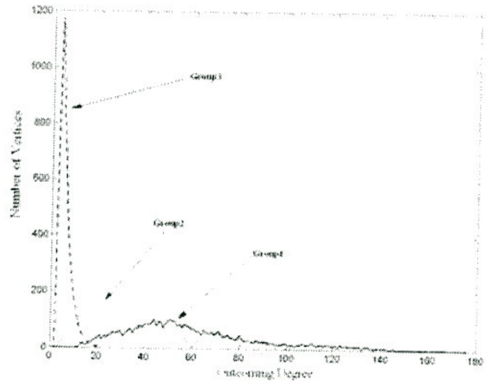

Figure 4. Outgoing degree distribution

From figure 3 and figure 4, we can see that incoming and outgoing degree distribution do not obey normal distribution, but power law distribution $k^{-\gamma}$. And γ of Group 3 in figure 4 is about 2.855, which is similar with result of [14]. In [14] γ of incoming edge degree of internet in 1997 is about 2.72.

The average path length of Group 1, Group 2 and Group 3 are 3.54, 5.99 and 6.57 respectively. It is clear and easy to understand that average path length decreases when edges increased in the system. But it is different from the average path length of 16 from [14]. The reason may lie in its relatively small size of simulation when compared with real world internet.

From above simulation, we can see that this algorithm is reasonable in modeling grid services. The following experiments are to simulate system when some service providers quit grid system and stop to provide their services dynamically. In this case, related vertices and all edges pointed to them and from them will be removed in directed graph. We will show relationship about probability of successfully accessing to a service versus probability that service providers leave grid system and size of grid system through simulation.

Figure 5 shows the relationship when dynamic occurs randomly among vertices in grid system. Figure 6 demonstrates the relationship when vertices with top highest incoming degree are removed from system.

The axes *X* in figure 5 and figure 6 represent number of service providers, *Y* represents probability that every service provider stops providing service and *Z* represents probability that a client can access all services in the system.

From figure 5, we can find that when vertices are randomly removed from graph, remaining vertices are still well connected and this property will not change when size of directed graph varied. In this situation, the only reason for a service can not be accessible is it left grid system for some reason. While in figure 6 when vertices with highest incoming degree are removed, the rest of vertices are not necessarily connected and some isolated sub graph thus formed. The reason for a service can not be accessed may lie in its provider left the system or it is still in system but the path from clients to it was cut.

Table 1. Parameters in simulation

	m_0	M	N	p_1	p_2	n_0	n_1	n_2
Group1	3	100	5000	0.1	0.1	10	40	50
Group 2	3	100	5000	0.02	0.02	5	15	20
Group 3	3	100	5000	0.01	0.01	1	2	3

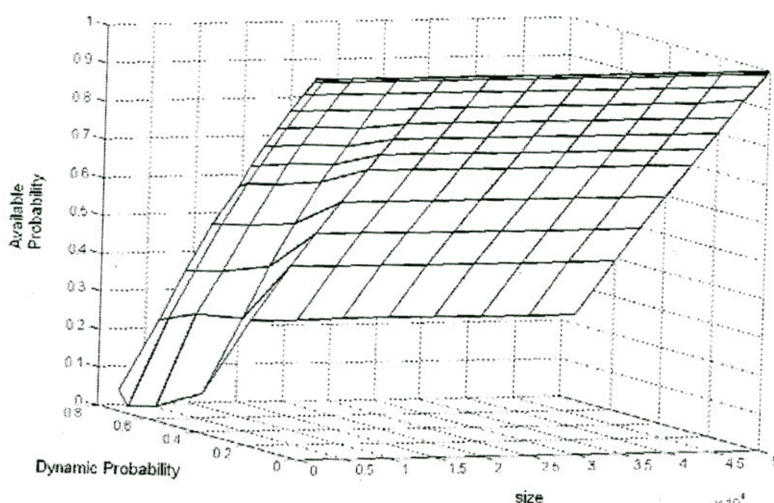

Figure 5. Relationship among size, dynamic probability and access probability under random dynamic condition

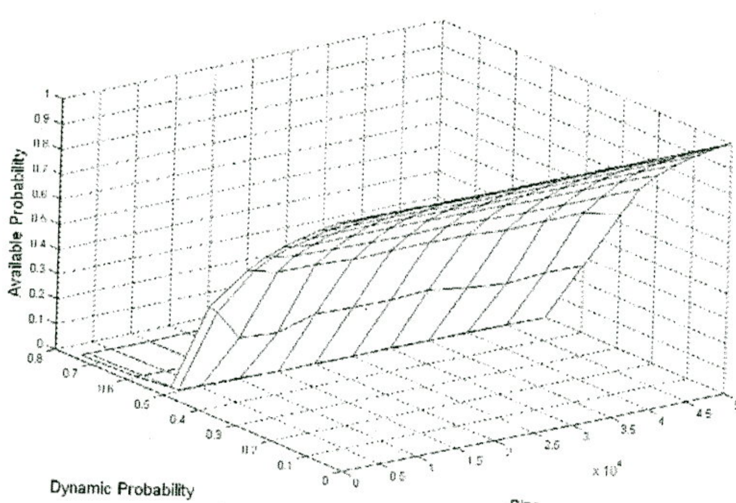

Figure 6. Relationship among size, dynamic probability and access probability under preferential condition

As can be seen from figure 6, services in the system can hardly be accessed when dynamic probability amounts to 50 percent, which results from the fact all vertices are almost isolated and edges among them have been removed away. In real world, most dynamics occur randomly except in case of malicious intrusions.

5. Conclusion and Future work

From simulation, it can be found that system building up through this algorithm, shows its robustness even under large randomly dynamics. The contribution of this algorithm to real world system is that it can provide some experience for new service providers in grid system. When a service provider wants to join a virtual organization in grid system, it should let some services know its existence by providing its URI into these services accessible lists, which are databases recording their accessible services. At the same time it should record some services URI to provide invocation when necessary. According to simulation, if a service is known by a little number of clients, it will be known by the entire system, taking no consideration of the security and authorization issues.

Future work includes the following three aspects.

1. The costs to access a service. Above work shows probability of accessibility to a service but the cost is not considered. Costs includes how to find a service that is valid, optimal path to reach the service and how to select a more suitable one when there are many similar services. One possible way is to choose services with highest outgoing degree and assign them a more important role in the system, such as distributed service schedulers. Any new service provider should connect to at least one of this kind of schedulers to show their existence.

2. When authorization and authentication is considered, the transitivity of connections among vertices will be challenged. How to incorporate security issues into this model deserves future work.

3. How to make full use of every vertex in the system and schedule jobs to the most suitable providers in order to balance throughput of the whole system and every vertex in the system needs further consideration. Because service providers with heavy load will inevitably keep their clients waiting in the queue while providers with low utilization will lose their interests in providing services for share in grid.

6. Acknowledgements

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