G2G: A Meta-Grid Framework for the Convergence of P2P and Grids

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Abstract. Grid systems integrate distributed resources to form self-organization and self-management autonomies. Recently, for large-scale computation requirement, the collaboration of different grid systems is one of the hot research topics. In this paper, we propose a meta-grid framework, called G2G framework, to harmonize autonomic grids for realizing the federation of different grids. The G2G framework is a decentralized management framework on top of existing autonomic grid systems. It adopts a super-peer network to coordinate distributed grid systems. A super-peer overlay network is constructed for the communication among super-peers in different grid systems. The contribution of this study is to propose a G2G framework for the Grid-to-Grid federation and to implement a preliminary system. Experimental results show that the proposed meta-grid framework could improve the system performance in the G2G system.

Keywords: Convergence, Peer-to-Peer (P2P), Super-peer, Grid Computing, Grid-to-Grid (G2G).

1 Introduction

The grid computing system is a distributed computing system for solving complex or high-performance computing problems, e.g., bioinformatics, medicare/healthcare, natural environment, large Hadron collider, and so on. The grid middleware enables the grid system to integrate large-scale distributed computing resources and to provide an abstract interface for system development. Then, the performance of distributed computing and data accessing could be improved by geographical distributed resources.

Many efforts adopt centralized or hierarchical architectures to develop grid systems based on the open grid service architecture (OGSA) [8]. In grid computing, a virtual

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N. Abdennadher and D. Petcu (Eds.): GPC 2009, LNCS 5529, pp. 131–141, 2009.

organization is a self-organization and self-management group which shares the same computing resources [7]. Recently, for large-scale computation requirement, the collaboration of different grid systems (G2G grid system or meta-grid system) is one of hot research topics. The prospective cooperation is to integrate multiple autonomic virtual organizations through the federation of distinct grid systems. However, it is a challenge to harmonize grid systems without bringing a heavy burden on existing grid infrastructure.

In order to coordinate multiple grid systems, a grid system requires a middleware for the cross-grid convergence of diversely autonomic grid communities. This burdens a grid system with lots of efforts to harmonize with other grid systems; and moreover, there is no mature cross-grid middleware for integrating with distinct grid systems. In this paper, we present a meta-grid framework, called G2G framework, to federate with multiple institutional grid systems. The G2G framework could harmonize distributed grid systems over the Internet with seamless modification for existing grid systems.

The proposed decentralized G2G framework could realize the synergy between P2P networks and existing grid systems. This study utilizes a super-peer network [14] to develop our G2G framework for the coordination of multiple autonomic grid systems. To achieve the decentralization of G2G framework, the super-peer network adopts an overlay network for the communication among super-peers in different grid systems through the federation of wide area grids. Our contributions in this paper are to introduce a conceptual framework of the G2G system based on a super-peer network. We also present a preliminary implementation of the proposed G2G framework and develop a Grid-to-Grid network based on an overlay network in which each grid system communicates and negotiates with other grid systems.

The remaining of this paper is organized as follows. Section 2 discusses the related work. In Section 3, we present a conceptual overview of G2G framework and the implementation of G2G prototype. The experiment results of G2G system are shown in Section 4. We conclude this paper with future work in Section 5.

2 Related Work

As the grid size increases, the scalability of the large-scale grid systems becomes one of the challenges. There are some works that have discussed the practices adopting the P2P technique to improve the scalability of the grid system. Some similarities and differences between P2P computing and grid computing have been presented in [5], [13]. Several previous works are aimed to improve the centralized-based infrastructure using the P2P technique. These related works are introduced in this section.

The integration of a distributed event brokering system with the JXTA technology [16] to enable Peer-to-Peer Grids has been proposed in [9]. The authors utilize NaradaBrokering [12] based on the hierarchical structure in the broker network. By the integration of NaradaBrokering and JXTA, services are mediated by the broker middleware or the P2P interactions between machines on the edge. The main idea of NaradaBrokering aims to present a unified environment for grid computing with a P2P interaction. In addition, the overhead would be costly for NaradaBrokering to maintain the broker network of the hierarchical topology in a dynamically changed network.

A P2PGrid platform based on a two-layer model for integrating P2P computing into the Grid is presented in [1]. All grid services are provided within the grid layer in a standard manner while the P2P layer is used for grid services or ordinary PCs to participate in the grid activities. In this study, JXTA is adopted to develop JXTA Agents to create peers, deal with dynamics of peer groups, and communicate with peers on the underlying P2P network. By the implementation of the P2PGrid platform, resources on the edge of Internet are able to provide or consume services without the hassles of maintaining grid middleware packages. A separate layer from existing grid system is benefit since the original behaves of grid layer could be preserved without modifications, and the modification of the P2P manner would not affect the efficiency of the grid layer. The main idea of the P2PGrid is to provide a possible solution for integrating P2P computing with the grid environment. Peers in the P2P layer are created by the grid entities or common PCs without any grid system installed. Jobs are requested and dispatched to workers organized by created peers in the underlying P2P computing network.

In this study, we present a decentralized meta-grid framework on the top of existing autonomic grid systems from another perspective. The autonomic grids are coordinated based on the super-peer network to form a Grid-to-Grid collaborative computing environment. A super-peer in the G2G system stands for a grid system. In this study, a super-peer is able to provide/consume the grid services to/from other super-peers in remote grid systems. The autonomic grids are coordinated based on a unstructured super-peer overlay network to form a Grid-to-Grid collaborative computing environment. By adopting a separated layer, the G2G framework could integrate with existing grid systems without modifying the original mechanisms and policies. On the other hand, we not only concern the support of computation services and data services, but also propose a possible solution for the verification of accessing remote resources because of considering the security issues in the Grid-to-Grid environment.

3 G2G Framework and Prototype

Currently, most of the grid systems are deployed according to centralized or hierarchical management approaches. However, these approaches have poor performance in terms of scalability, resiliency, and load-balancing for managing distributed resources [11]. Centralization and hierarchy are the weaknesses of deploying large multi-institutional grid systems, let alone in the widely inter-networking G2G system. Some research work showed that the performance with adopting the super-peer model is generally more efficient and convenient than that without adopting the super-peer model in large-scale computing environments.

In our G2G framework, we utilize the super-peer network to coordinate the existing grid systems and adopt the P2P technique to coordinate grid systems. In this section, we describe the design concept for G2G system at first; and then, we introduce a basic conceptual overview of meta-grid framework. At the end of this section, we present a preliminary G2G prototype for the development of the G2G system.

3.1 Super-Peer Based G2G System

The super-peer network is proposed to combine the efficiency of centralized search as well as the features in terms of autonomy, load balance, and robustness of distributed search. A super-peer is a node that acts both as a centralized server to a set of ordinary nodes and as a coequality to negotiate with other super-peers.

Each super-peer in our G2G system acts a coordinator for a single grid system which is built in self-organization and self-management with the autonomy. A super-peer in the G2G system is responsible for coordinating a local autonomic Grid system and negotiating with other super-peers in remote Grid systems. For example, after obtaining a request for task execution, the super-peer firstly checks whether the request could be processed locally; otherwise, the request would be forwarded to other grid systems by cooperating with other super-peers.

Since there are multiple autonomic grid systems in the G2G system, we set up a P2P network on the grid systems to federate the super-peer in each grid system. In this way, the Grid-to-Grid interactions among distinct grid systems are by way of the P2P network. Based on P2P overlay networks, each grid in the G2G system could supply its resources and services to other grid systems and improve the resource utilization in the wide-area grids when some of the grids are overloaded and some of them are under-loaded.

In order to achieve the seamless integration of the grids in the G2G system, this study adopts the super-peer network on top of the existing grid systems, and harmonizes existing autonomous grids with each other without rebuilding/modifying any grid system. Each existent grid system could easily join the G2G system based on the super-peer network. The concept of the G2G system is shown in Fig. 1.

The G2G system consists of the Cross-Grid part, the Local-Grid part and the Meta-Grid interface. In the Local-Grid part, it consists of some autonomic grid systems which are built by the grid middleware to collaborate distributed resources. In the Cross-Grid part, the super-peers are deployed and the G2G layer is responsible to coordinate the super-peers in autonomic grids. These super-peers not only take charge of integrating the autonomic grids by the developed common interfaces but also handle the negotiation between grid systems in the G2G layer. The Meta-Grid interface is responsible to integrate the Cross-Grid part and the Local-Grid part. Using these common interfaces, the Cross-Grid part could acquire the resources and services from

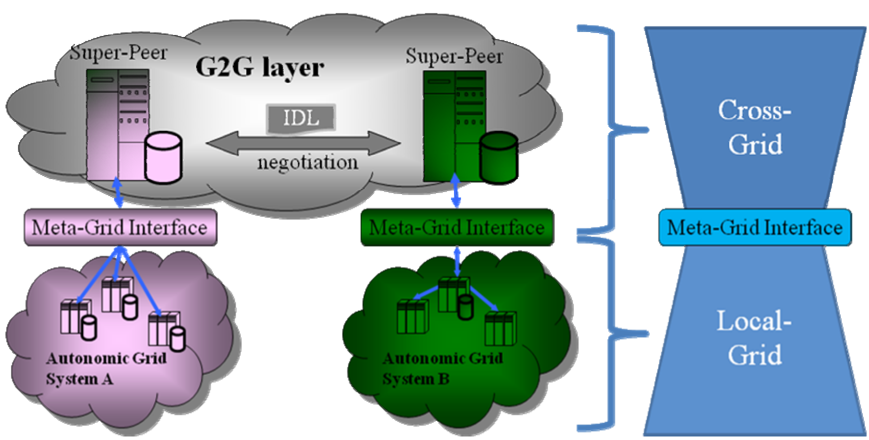

Fig. 1. Conception of the G2G system based on a super-peer network

the Local-Grid part without knowing the policies, mechanisms, or algorithms in the Local-Grid part. Since the Cross-Grid part and the Local-Grid part are independent, the Cross-Grid part doesn't need to be modified when the mechanisms in the Local-Grid part are modified or replaced.

3.2 G2G Framework

The G2G framework aims to support the seamless integration of the computing services and the data accessing services in the autonomous grids. Therefore, the super-peer in the Cross-Grid part consists of seven components: the Interactive interface, the security management, the network management, the task management, the data management, the resource management and the information service. The task management component takes care of the job computation, and the data management component is responsible for integrating the storage systems in the data grid [2]. The network management component handles the network topology and the G2G interaction between distinct grids. The resource management manages the distributed resources in grid systems according to the resource status supported by the information service component. The interactive interface component deals with the login process for users and the security management component is in charge of the authorization of using grids.

In this study, a meta-grid framework of the G2G system is proposed for federating multiple autonomic grid systems, as shown in Fig. 2. By cooperating these components in the G2G framework, we can apply grid applications on this framework. The detail notions of developing a G2G prototype are shown in the following.

3.3 G2G Prototype

This study uses JAVA to develop the proposed G2G framework in which the super-peers are connected by an unstructured overlay network. The developed components of the super-peer are deployed on top of each autonomic grid system to form the

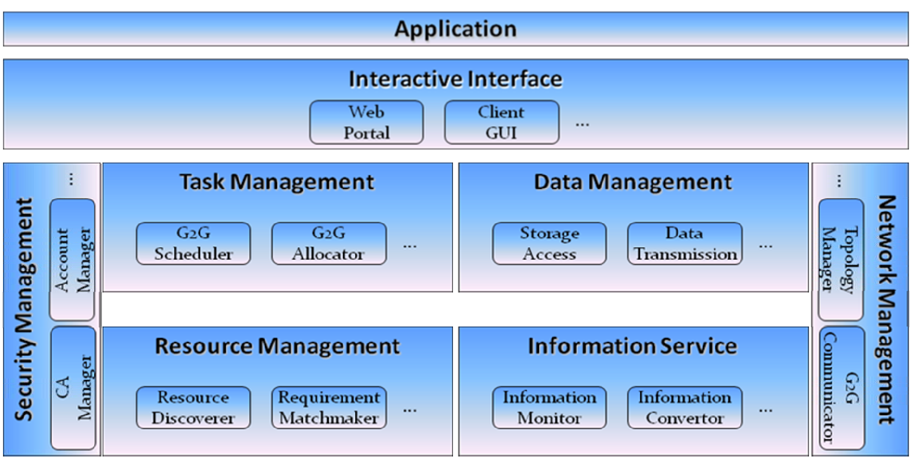

Fig. 2. Conceptual framework of components in the Cross-Grid part

federation environment. In this subsection, we describe the implementation and the cooperation of all components in the G2G computing system.

3.3.1 Portal and Single Sign-On

In general, a friendly interactive interface is important for users while using the grids. Therefore, this study develops a uniform web portal for users to easily enter a grid system and to utilize the authorized resources and services. There are two important functions for developing a uniform web portal: *Single Sign-On (SSO)*, and *workflow operation*.

Single Sign-On (SSO) is adopted for users to access the grids with only-once login. Each user could utilize grid resources/services after the successful verification through the proxy server and the security management. This study proposes a uniform web portal on top of each autonomous grid system. A redirection mechanism is also developed in the uniform web portal.

When a user logins the G2G system from this uniform web portal, the portal would determine which grid system the user should be entered according to the user's login information. The candidate grid system would verify whether the user's login information is valid or not. If the login is successful, the portal would deliver the user's login information to the local security service through the Meta-Grid interface. If the certificate of the user is also valid, the login process is successful and complete. Otherwise, it would be a failure one. Since the login process is accomplished through the integration of originally grid systems, the SSO in the G2G layer could be subsisted if the local grid supports the SSO mechanism.

The workflow operation in the G2G system supports the task submission. A workflow is composed of multiple stages and each stage is composed of multiple jobs. Jobs between distinct stages may be dependent. But jobs in the same stage are all independent, that is, all jobs within the same stage could be scheduled and allocated for simultaneous execution.

This study also develops a workflow editor in the uniform web portal. According to the resource status obtained from the information service component, users could not only edit the tasks on the portal, but also specify desired resource requirements. This study adopts an XML-based structure language to describe the task information and supports the resource discovery by multiple attributes with range query. After the task submission, the edited workflow would be transformed into the XML-based form and be stored in the database for users to lookup, cancel, or refine their tasks at anytime.

3.3.2 Security Service

Grid authentication and authorization are key services in the grid security management. Grid Security Infrastructure (GSI) [6] has defined the standard for the legal utilization of grid services. In the G2G system, the security management component deals with not only the certificate authorization locally, but also the admission request from remote grid systems. The issues of the secrecy and privacy in the G2G system have to guarantee the original legal services in the local grid systems and accept the permission of utilizing local resources/services for other remote grid systems. The security management component includes two primary parts: the passport manager for the authorized privilege and the account manager for the account management.

Passport manager takes care of the passport registration and the verification in the G2G system. A passport stands for the admission or verification of the request from remote grid systems. If one grid system wants to access resources in another grid system, it must get a visaed passport from the target grid system before accessing the resources. This study develops a distributed passport-interchange-mechanism in the G2G system. According to the maintenance of neighborhood relationship, each grid system could request a remote resource/service from its neighbors or neighbors' neighbors by forwarding the resource/service request along the overlay network. After discovering the available resource/service in remote grids, the requester would receive the visaed passports from the granted grid system; and then, the requester could submit tasks to the granted remote grids with legal permission.

Account manager is responsible for the account management. In this study, the function of the account authentication is used for a "local account" to login the grids. A local account indicates an originally user account in the local grid system. Once an account requests for a login from the portal, the portal would ask the account manager to verify its identification. Another important issue of the account manager is the account mapping mechanism. Account mapping is used to deal with requests issued by foreign users from remote grid systems. Every grid system which wants to use the resources in other grids must register to the granted grid system before accessing those resources. The register process acquires a passport and gets a temporary account. Once the register process is completed, every request with the visaed passport from remote grid systems would be treated as a local user account through the account mapping mechanism.

3.3.3 Data Service

In this study, the G2G system supports specific APIs for the transparent accesses of existent data storage in each local grid system and for the data transmission among different autonomic grid systems.

In the G2G system, the abstract APIs is responsible to contact a storage system in a local grid system or a general file system. Data accesses between the Cross-Grid layer and the Local-Grid layer adopt the general-defined data operations; otherwise, the data accesses from one grid to another grid adopt the G2G communication through super-peers. When a data transmission is necessary to communicate with remote grids, the super-peer takes care of the negotiation and communication with other super-peers in the G2G layer. We use the account manager to manage the foreign data files in this case. When the data files are accessed from remote grid systems, these data files could be stored in the storage system and then be mapped to local owners. After the data mapping and the account handling, the foreign data file could be accessible for local users.

3.3.4 Information Service

The main responsibilities of the information service include the resource indexing and monitoring for capturing the resource status in a grid system. Traditional Grid Information Service (GIS) generally adopts the centralized or hierarchical organization [3], [4]. Such architectures for the information service are hard to directly apply to the G2G system because of the single point of failure problem. To alleviate the failure problem, this study develops an information service for crossing the inter-grid systems on top of the existent information monitoring system. Our information service consists of two mechanisms: the information monitor and the information convertor.

This study also proposes an Information Description Language (IDL) in the form of the XML-based structure for describing the grid information in the Cross-Grid layer. The IDL is composed of many kinds of information such as task submission, task requirement, resource status, system utilization, and so on. Since the XML-based structure is wide used for information monitoring systems to record resource information, we also develop the information convertor to inter-transform other XML-based resource information into our IDL format.

3.3.5 Network Management

This study proposes a Grid-to-Grid overlay network based on the super-peer network. In the G2G system, the super-peer in each autonomic grid system takes responsible for the negotiation and communication with other super-peers over the G2G overlay network. The decentralized overlay network is adopted to construct the neighborhood relationship and to forward a request between super-peers.

In the cross-grid network management, we introduce the topology manager to maintain the overlay network with an adaptable mechanism for the neighborhood relationship or routing information. On the other hand, we also present the G2G communicator to take care of the network communication and message negotiation. In order to communicate with different autonomic systems, we not only apply IDL to describe the exchanged information but also design an application-level request format for message transmission. Every communication is accomplished by using the socket connection. The communication in-between two grid systems could be divided into sender- and receiver-modules. For the sender module, all the requests would be transformed into a predefined request format, and then the requests are sent to remote super-peers in serial. For the receiver module, remote super-peer de-serializes all the received requests and forwards to the corresponding components.

3.3.6 Task Management with Resource Discovery

The task management is in charge of the task submission through the interactive interface. A task would be a number of jobs executed in sequential or in parallel. In the G2G system, tasks are not only submitted from local users, but probably are requested from remote grid systems. The G2G scheduler and G2G allocator need to consider the job execution among the intra-grid submission as well as the inter-grid submission.

In the task management module, we adopt a workflow structure to organize jobs in a predefined order for execution. The workflow structure is constructed by stages and jobs. Those jobs in next stage must be waiting for execution until all jobs in current stage are finished because of considering the relations between stages are dependent. We also develop the workflow manager and the job manager to handle requested tasks. After a task is submitted to workflow manager, the manager schedules the order of jobs and decides where to execute these jobs. The decision of migrating the executable jobs to a local grid or a remote grid depends on the system performance or the current resource condition. Each job has its basic requirements of desired resources or the computing environment for execution. This study also applies a resource discovery mechanism [10] to explore distributed resources status over the Grid-to-Grid overlay network, and supports a matchmaking policy to provide candidate resources satisfied the specified requirements.

After a task is submitted to the waiting queue for execution, the G2G scheduler picks one of queuing jobs according to the First-Come-First-Served (FCFS) policy, and then checks whether local resources are sufficient or under loading at first. The decision of where to execute a job depends on not only checking whether local grid system is over loading, but also discovering whether local resources are satisfied with requirements through information service. If the local grid system is not busy and there are sufficiently available resources, the job would be migrated to the local grid system to be executed. Otherwise, the job manager would ask the distributed resource discovery module to search available resources over the overlay network. If there are sufficient resources in other super-peers, the job would be migrated to the remote grid system for execution. Otherwise, this job would be queued in the waiting queue for available resources.

4 Experimental Results

To evaluate the proposed G2G framework, two autonomic grid systems based on the framework of Taiwan UniGrid [15] are used. One autonomic grid system contains a cluster with 8 higher computational power CPUs. The other autonomic grid system contains a cluster with 32 lower computing power CPUs. We deploy the proposed super-peer network on top of each autonomic grid system to form a Grid-to-Grid federation environment. Each super-peer is responsible for coordinating the local autonomic grid system and for communicating with other super-peers over the Internet. By using the information converter, each grid system in the G2G system could extract resource information from the Information Service module. By using the IDL, the Cross-Grid layer could negotiate with the Local-Grid layer; and then the message could be exchanged between distinct grid systems.

We use a matrix multiplication program as the benchmark. Each job we used in the experiment is a parallel program written by MPI with C. The matrix size is 2048x2048. The number of required processors for each job is set to 2. The ratio of communication to computation of the test program is about 1 to 100. The task we used for performance evaluation is composed of five independent jobs. We estimate the average turnaround time for finishing all the jobs in three cases. The turnaround time of a task is defined as the time when a task is submitted to the waiting queue for processing in the Cross-Grid layer to the time when all the jobs are finished in the Local-Grid layer. In case 1, the task is submitted to the grid system with rich resources but lower computing power. In case 2, the same task is submitted to the grid system with fewer resources but higher computational power. For cases 1 and 2, all the jobs are only executed in the local grid system. In case 3, the same task is submitted to the G2G system that contains both grid systems. In this case, jobs will be executed in the local grid or the remote grid according to the decision made by the G2G scheduler and G2G allocator that we described in Section 3.3.6.

Fig. 3 shows the experimental results of three cases. The experimental results show that the proposed meta-grid framework could improve the system performance in the G2G system. In general, a grid system with rich resources could finish a task with less

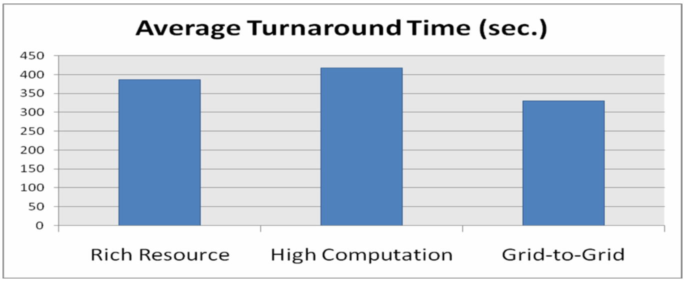

Fig. 3. Experimental results for finishing executing a task in three cases

turnaround time than that with higher computational power. The reason is that a job would be queued for a long time if local resources are all busy in a grid system with fewer resources. The longer time a job is queued, the more time the turnaround time would be consumed. When there are no available resources in a local grid system, the job would be migrated to a remote grid system with available resources for execution. Hence, a task in the G2G system would be finished with the least average turnaround time.

5 Conclusions and Future Work

Integrating the P2P technique with grid computing could improve the scalability of the large-scale grid system. This study proposes a meta-grid framework, named G2G framework, for the Grid-to-Grid federation of autonomic grid systems without modifying the original mechanisms and policies. Based on the super-peer network, we adopt a separated layer on top of existing grid systems to develop the Grid-to-Grid collaborative computing environment. A super-peer in the G2G system is responsible for coordinating an internally autonomic grid system and for communicating with other super-peers. The overlay network among super-peers is constructed by the unstructured approach.

A grid system is deployed with the capacity of the super-peer for coordinating the G2G system. With the well-defined APIs, the G2G system looks like an abstract layer separated from the existing grid systems. In our G2G system, an existing grid system could upgrade its G2G capability without upsetting original mechanisms. We not only take care of the support of computation services and data services, but also consider a possible solution for the grid security across different grid systems. To evaluate the performance of the G2G system, we implemented a preliminary system to show that the proposed system not only is workable but also improves the system performance.

We will continue to integrate with more autonomic grid systems and study on the efficiency of grid security across diverse grid systems. We also intend to integrate the G2G framework with the Service-Oriented Architecture (SOA) to develop a service-oriented G2G computing system in the future.

Acknowledgments. The work of this paper is partially supported by National Science Council, Ministry of Economic Affairs of the Republic of China under contract NSC 96-2221-E-007-129-MY3 and NSC 96-2221-E-007-130-MY3. We also thank all of the people for comments and advices.

References

1. Cao, J., Liu, F.B., Xu, C.-Z.: P2PGrid: Integrating P2P Networks into the Grid Environment: Research Articles. Concurr. Comput.: Pract. Exper. 19, 1023–1046 (2007)
2. Chervenak, A., Foster, I., Kesselman, C., Salisbury, C., Tuecke, S.: The Data Grid: Towards an Architecture for the Distributed Management and Analysis of Large Scientific Datasets. Journal of Network and Computer Applications 23, 187–200 (2000)
3. Czajkowski, K., Fitzgerald, S., Foster, I., Kesselman, C.: Grid Information Services for Distributed Resource Sharing. In: 10th IEEE International Symposium on High Performance Distributed Computing, pp. 181–194. IEEE Press, New York (2001)
4. Fitzgerald, S., Foster, I., Kesselman, C., von Laszewski, G., Smith, W., Tuecke, S.: A Directory Service for Configuring High-Performance Distributed Computations. In: Sixth IEEE International Symposium on High Performance Distributed Computing, pp. 365–375. IEEE Press, Los Alamitos (1997)
5. Foster, I., Iamnitchi, A.: On Death, Taxes, and the Convergence of Peer-to-Peer and Grid Computing. In: Peer-to-Peer Systems II, pp. 118–128 (2003)
6. Foster, I., Kesselman, C., Tsudik, G., Tuecke, S.: A Security Architecture for Computational Grids. In: 5th ACM Conference on Computer and Communications Security, pp. 83–92. ACM, San Francisco (1998)
7. Foster, I., Kesselman, C., Tuecke, S.: The Anatomy of the Grid: Enabling Scalable Virtual Organizations. International Journal of High Performance Computing Applications 15, 200–222 (2001)
8. Foster, I., Kesselman, C., Nick, J.M., Tuecke, S.: The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration. Technical Report. Global Grid Forum (2002), `http://www.globus.org/alliance/publications/papers/ogsa.pdf`
9. Fox, G., Pallickara, S., Rao, X.: Towards Enabling Peer-to-Peer Grids. Concurr. Comput.: Pract. Exper. 17, 1109–1131 (2005)
10. Mastroianni, C., Talia, D., Verta, O.: A Super-Peer Model for Resource Discovery Services in Large-Scale Grids. Future Generation Computer Systems 21, 1235–1248 (2005)
11. Mastroianni, C., Talia, D., Verta, O.: Evaluating Resource Discovery Protocols for Hierarchical and Super-Peer Grid Information Systems. In: 15th Euromicro International Conference on Parallel, Distributed and Network-Based Processing, pp. 147–154. IEEE Press, Los Alamitos (2007)
12. Pallickara, S., Fox, G.: NaradaBrokering: A Distributed Middleware Framework and Architecture for Enabling Durable Peer-to-Peer Grids. In: Endler, M., Schmidt, D.C. (eds.) Middleware 2003. LNCS, vol. 2672, pp. 998–999. Springer, Heidelberg (2003)
13. Talia, D., Trunfio, P.: Toward a Synergy between P2P and Grids. Internet Computing 7, 96–95 (2003)
14. Yang, B., Garcia-Molina, H.: Designing a Super-Peer Network. In: 19th International Conference on Data Engineering, pp. 49–60 (2003)
15. Po-Chi, S., Hsi-Min, C., Yeh-Ching, C., Chien-Min, W., Ruay-Shiung, C., Ching-Hsien, H., Kuo-Chan, H., Chao-Tung, Y.: Middleware of Taiwan UniGrid. In: 2008 ACM symposium on Applied computing, pp. 489–493. ACM, Fortaleza (2008)
16. JXTA Community Projects, `https://jxta.dev.java.net/`