Grid Resource Information Frameworks*

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Abstract. *The choice of a suitable information model is a key step to successful deployment and use of the Grid infrastructure. It has to meet strong requirements for scalability, robustness and performance in the heterogeneous and dynamic Grid environment.*
In this paper the main characteristics of the Grid information models are reviewed. The basic challenges that have to be taken into account: architecture, data distribution and replication, functionally complete Grid entity sets, etc. are adressed.
Finally an overview of existing concepts for information representation in Grid is presented and a comparison of the particular realizations of information services based on LDAP, RDBMS and UDDI is provided.

1. Introduction

The Grid Information Service (GIS) is a complex architecture that maintains structured, uniform and meaningful information about services in the heterogeneous and dynamic Grid environment, in order to support the discovery, selection and optimal utilization of its resources. As the scale and diversity of the Grid infrastructure are growing, the information needed for efficient management becomes crucial [1].

GIS is closely connected to the other Grid services. Job execution in the grid environment relies on timely access to accurate and up-to-date information for resources and services, spread over wide area. Resource Management Service must be able to locate a suitable operational site (OS, CPU, storage capacity, data sources) as well as to examine current and expected system state (CPU utilization, available storage space, etc.) in order to achieve efficient job scheduling. It is important GIS to provide regular information about job progress too. Security service also interacts with GIS in order to authenticate and authorize users. Another user of the GIS is the Grid portal, whose functionality is based on the information gathering by GIS.

In particular, when an abnormal situation happens, the recent information could be very useful in the subsequent analysis for reconstruction of the events that have led to the failure.

The collected data may be used to optimize the system behaviour according to the conditions on the fabric.

2. Information Models in Grid

The information model integrates appropriate technologies and data structures in order to create a robust and reliable GIS. The choice of suitable information model is very important for the successful deployment and use of a Grid infrastructure.

Below are listed some issues concerning GIS data design features. In the next section is presented the GIS technological overview.

2.1. Main Requirements to the Data Provided by GIS

The main postulate is that GIS provides information about valuable data objects. Entities in GIS, whose real-world representations are the objects, build clear and uniform abstract layer over the heterogeneous grid resources.

The candidates for GIS entities must meet a number of criteria [1]:

- Usefulness – the entity includes only the valuable attributes (only meaningful information).
- Uniqueness – the entities are distinguishable from each other (the user can choose one particular entity among all entities of the same type)
- Persistence – the entity is long lasting (transient data, which appears accidentally or extremely rarely, are not candidates for entities).
- Generality – the entity is valuable for multiple applications or users.

Entities have to be capable of joining other entities or belonging to more than one category if their functionality requires that. Hence the data model must support complex relationships between entities.

2.2. Kind of Data that GIS Must Support

GIS must ensure functionally complete Grid entity set. That means to present the whole variety of entities which comply with the data model outlined above. For instance [1,6]:

- Static Host Information (operating system, version, processors, hostname, etc.).
- Dynamic Host Information (load average, CPU usage, running processes, etc.).
- Network Information (topology, bandwidth, latency, etc.).
- Storage System Information (total disk space, available disk space, etc.).
- Applications (software, data, active services, etc.).
- Users (users, credentials, roles, etc.).
- Organisations (name, security policies, etc.).
- Instruments (radars, etc.).

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2.3. Some Considerations about Data Dynamics

Very important aspect of Grid data model is data dynamics (which shows how it has changed over time). Such statistics could be used for: resource management; billing in economic grid; system crash investigations; host load forecasting and so on. As a result, data schema supporting tracks for objects' changes is crucial. According to the dynamics, there are discrete value's data (last state, historical records for past period) and continuous data streams (that reflect resource's dynamics on the fly). Despite of the different ways of using data, however, it is desirable to have a uniform representation that includes for example mandatory timestamp attribute.

3. Requirements for Grid Information Services

Except for the data model, the investigation of the underlying characteristics, technologies and approaches is a key step to successful deployment and efficient use of the Grid infrastructure. There are several aspects that have to be examined in order to acquire a clear notion of the GIS architecture [1,2].

3.1. Centralised vs. Decentralised Approaches

A centralised approach (maintaining single data repository) is very easy to manage. Provider-centric GIS ensures that the platform is freed from complex data modelling and binding issues [2] but it introduces a lot of problems, such as:

• Performance: It could be a performance bottleneck if all resources direct their data streams to a centralized information server.

• Scalability: When the number of clients grows, a single information centre may have inadequate capacity to process all the requests.

• Fault tolerance: When the centralized server is not active the whole system would stop. It will be restored only after the information server is on line.

A decentralized approach (distributed repositories), on the other hand, is much more difficult to manage, involves communication and synchronization overheads but ensures more reliable and flexible background for a GIS. The considerations mentioned above are no longer obstacles to good GIS realization. But there are some others:

• Distributed Search: In a decentralized environment meta-data is spread over a large area. To obtain relevant information a number of repositories must be accessed. Distributed search means retrieving data from spread information centres and combining results in fast and efficient way. Performance can be significantly improved through indexes which collect and aggregate frequently used data.

Any topologies are possible but a combination of the two strategies sounds more feasible for a grid environment. We assume that the greatest part of the activities is in the bounds of administrative domains (logical cluster) and inter-communications are less. So, centralized information schema on local level and distributed peer-to-peer infrastructure that prov ides global view is the most reliable GIS architecture.

3.2. Fault Tolerance

GIS must be able to cope with unexpected events which could affect resource availability in a flexible manner (adaptation). Decentralized GIS schema is the right approach for the case because it protects the Grid from total crash in case of failure of any of its modules. However, in order to ensure more reliable and fault tolerant environment, a backup strategy must be available. For example: a primary GIS instance stores data in a memory or on disc and synchronizes data with standby GIS (which would be used in case of crash or for optimization). Some of the data (metadata and job states) are crucial for GIS functioning and they must be secured on reserve site almost immediately. The rest persistent data (mainly historical) could be delivered with some delay. The main aim is (fast) recovering from abnormal situations: fallen off GIS in short time must be replaced with relevant up-to-date GIS instance.

3.3. Reconfiguration and Adaptability

The ability of the platform to self-organise itself is a vital prerequisite for resilience to failures. The platform should give an opportunity for dynamic addition and removal of GIS instances as an appropriate reaction to changes in the environmental conditions.

In supporting reconfiguration and adaptability, the platform may utilise rules and knowledge, gathered across runs.

3.4. Replication and Caching

In the context of data grid technologies, replication is mostly used to reduce access latency and bandwidth consumption. The other advantages of replication are that it helps in load balancing and improves availability by creating multiple copies of the same data. Obtaining precise information on time is an important requirement for the GIS and replication and caching are extremely good strategies for achieving it. Frequently needed data can be locally cached and reused. An important question is how stale the information is. A mechanism is necessary to guarantee data „freshness". Providing Time To Live (TTL) attribute, indicating how much time data can be used, is a good choice.

However, when multiple GIS schemas' copies are available, how is data consistency provided? Static meta-data is less sensitive to changes and isolated synchronization delays are not so critical. However, latencies in dynamic data synchronization result in returning outdate information, which in turn could lead to inefficient scheduling decisions.

3.5. Security

In a Grid environment security is a complex problem. In order to address robust authentication and commu-nication protection demands a suitable security infrastructure should be built. Adoption of too severe security policy could become performance problem. In general, GIS schema contains resource characteristics and statuses of current and completed jobs, which are not strictly confidential. So, balance between reliable security level and adequate performance should be found.

3.6. Open Standards and Open Source Tools

Applying open standards and protocols and well known tools has as consequence improved scalability and better tools support as well as sharing development experience. The fundamental direction for building a flexible and reliable GIS infrastructure should be: open standards, open source tools and portable implementations (based on Java). Whenever open standard or tools agree with grid project specifications it is better to use them.

4. Overview of Existing Information Technologies

As already mentioned, the most flexible solution for a GIS uses a common infrastructure that merges static information and dynamic monitoring data and provides a uniform schema for both operational and historical information. Grid Monitoring Architecture (GMA), proposed by Global Grid Forum, models grid information as a set of producers (that provide information), consumers (that request information) and a single registry (integrated repository that mediates the interaction between producers and consumers). Furthermore, the GMA supports rich set of interfaces for data exchange: publish/subscribe; query/response and event notification [3,4,5,11,13].

Currently, there are two main approaches to information representation: hierarchical and relational. The hierarchical model models objects as entries in trees. One of the objects is a root of the tree and the rest are related to it. It supports only one type of relationship: parent-to-child („is-a"). The relational model represents the object type as a relation; the objects are themselves tuples of the relation. It allows peer-to-peer relationships („part-of") between relations.

4.1. LDAP

The Lightweight Directory Access Protocol (LDAP) is an open network protocol for querying and modifying directory services running over TCP/IP. The LDAP namespace is based on entries which are joined in hierarchical Directory Information Tree. LDAP is designed for information retrieval rather than for updating information, and offer a static view of the data.

The Globus Toolkit provides application developers with a hierarchical GIS infrastructure called Metadata Directory Service (MDS2) using LDAP. It consists of two components: Grid Resource Information Service (GRIS) and Grid Index Information Service (GIIS). The GRIS supplies information about primary resources, while the GIIS aggregates information from multiple GRIS sources and provides a virtual scope for fast searching [7,12,13].

4.2. Relational Approach

Relational Grid Monitoring Architecture (R-GMA) presents the information resources as a virtual database containing a set of tables with complex relationships among them. Note that R-GMA is not distributed relational DBMS but rather a way to use relational principals in distributed environment (consistency requirement is not so emphasized in some cases) [6,8,10,11,13].

Besides producers and consumers, R-GMA provides two other components: schema and registry. A schema contains the name and structure (column names, types and description) of each virtual table in the system. A registry contains a list, for each table, of producers who insert rows (publish data) for that table i.e. it maps producers to the logical database table they produce information for. On registration the producer uses SQL WHERE predicate to define which partition of table data it will populate. The data itself is inserted into logical table through SQL INSERT statement. There is also an archives component (secondary producer) that combines and filters information streams from multiple producers and archives them in a database.

The consumers run SQL SELECT query on the virtual database in order to fetch necessary records. The query is first checked against the registry to identify which producers, for each virtual table in the query, must be contacted. The query is then passed to each relevant producer, to obtain the answer tuples directly. There is no central repository holding the contents of the tables; it is in this sense a virtual database.

The main advantage of the model is that the infrastructure relies on relational DBMS, which is a proven and effective technology for both fast reading and writing and there are many people familiar with relational DBMS products [6].

4.3. UDDI

UDDI, the Universal Description Discovery and Integration, is a Web Services registry standard, which provides a data model for describing businesses services. There is also the Universal Business Registry (UBR), which is a global public registry for advertising the available services. In addition UDDI can be set up as a private or community registry [9]. However, it is a technology suitable mostly for static data.

The Globus' Monitoring and Discovery System (MDS4) is a suite of web services to monitor and discover resources and services on Grids. MDS4 includes two Web Services Resource Framework (WSRF)-based services: an Index Service, that gathers data from various sources and a Trigger Service, which can be configured to take action when pre-defined trouble conditions are met. The Index Service is a registry similar to UDDI, but much more flexible. Clients use standard WSRF resource property query and subscription/notification interfaces to retrieve information from an Index. Indexes can register to each other in a hierarchical fashion in order to aggregate data at several levels. An additional Archive Service provides access to historical data [7].

A short comparison of the methods is presented on *the table.*

5. Conclusions

The successful deployment and use of the Grid infrastructure strongly depends on the choice of a suitable information model. The above review of the existing information technologies can help in that aim. The hierarchical data model is well suited to the distribution needs of the computational grid because the rooted tree lends itself well to partitioning into subtrees by administrative domains. UDDI, as the newest and promising tendency in the Grid information infrastructure, has

	LDAP	Relational Model	UDDI
Advantages	Open standard,widespread protocol. Extensible information model Directories can be distributed and replicated to provide scalability and reliability.High level of data protection and data access. Standard Internet protocols for data access.	Extendable model (additional information can be added very easily).There are many people familiar with relational DBMS products.	Open and increasingly supported standard.Flexible and scalable.
Disadvantages	Poor update performance. A huge amount of data can not be efficiently managed. For unusual questions, getting an answer could be very expensive. The LDAP query language is limited (for example there is no join operation). Radical changes in the informational model are not possible.	Relational DBMS are based on strict ACID principles, but in GIS this strong conditions could lead to performance problems. Some of the systems are too complex and too hard for administration. The using of data partitioning for a security policy is a more difficult task for multiple administrative domains.	Difficulties in handling dynamic information that requires frequent updating. No explicit data typing for information in the UDDI directory. Limited query language

a potential to become a steady platform for GIS. However, from the presented technologies the relational approach largely covers the GIS requirements and ensures the most suitable platform for building reliable and robust GIS based on optimal environment for data manipulating.

Certainly, when choosing the proper platform, some other considerations like fault tolerance, data distribution, replication, and consistency are essential as well.

References

1. Plale, B., P.Dinda, G.von Laszewski. Key Concepts and Services of a Grid Information Service. ICDCS 2002.
2. Badia, R., O. Beckman, M. Bubak, D. Caromel, V. Getov, S. Isaiadis, V. Lazarov, M. Malawski, S. Panagiotidi J. Thiyagalingam. Lightweight Grid Platform: Design Methodology. October 2005.
3. Zhang, X., J.Freschl, J.Schopf. A Performance Study of Monitoring and Information Services for Distributed Systems. HPDC-12, 2003.
4. Byrom, R., B. Coghlan, A. Cooke, R. Cordenonsi, L. Cornwall , M. Craig, ,A. Djaoui, S. Fisher, A. Gray, S. Hicks , Kenny, J. Leake, O. Lyttleton, J. Magowan, R. Middleton, W. Nutt, D. O'Callaghan, N. Podhorszki, P. Taylor, J. Walk, A. Wilson. Production Services for Information and Monitoring in the Grid. UK e-Science Conf., September 2004.
5. Coghlan, B., A.Djaoui, S. Fisher, J. Magowan, M. Oevers. Time, Information Services and the Grid. May 2001.
6. Dinda, P., B. Plale. A Unified Relational Approach to Grid Information Services. February 2001.
7. Aloisio, G., M. Cafaro, I. Epicoco, S. Fiore. Analysis of the Globus Toolkit Grid Information Service. Version 1.
8. Allan, R., D.Chohan, X. Dong Wang, A.Richards, M. McKeown, J. Colgrave, M. Dovey, M. Baker, S. Fisher. Building the e-Science Grid in the UK: Grid Information Services. UK e-Science Conf., September 2003.
9. Benson, E., G., Wasson, M., Humphrey. Evaluation of UDDI as a Provider of Resource Discovery Services for OGSA-based Grids. April 2006.
10. Holub, P., M. Kuba, L. Matyska, M. Ruda. Grid Infrastructure Monitoring as Reliable Information Service. Second European AcrossGrids Conference, 2004.
11. Cooke, A., A. Gray, Ma L., W. Nutt, J. Magowan, M. Oevers, P. Taylor, R. Byrom, L. Field, S. Hicks, J. Leake, M. Soni, A. Wilson, R. Cordenonsi, L. Cornwall, A. Djaoui, S. Fisher, N. Podhorszki, B. Coghlan, S. Kenny and D. O'Callaghan. R-GMA: An Information Integration System for Grid Monitoring. ICCIS, 2003.
12. Aloisio, G., E. Blasi, M. Cafaro, I. Epicoco, S. Fiore, M. Mirto. Dynamic Grid Catalog Information Service. First European Across Grids Conference, 2003.
13. Dikaiakos, M., R., Sakellariou. Information Services for Large-Scale Grids: A Case for a Grid Search Engine. CoreGRID Technical Report, 2005.

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References

1. Pavlov, V. Efficient Quantum Computing Simulation.Proceedings of IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing. IEEE Computer Society Press, 2006, 235-239.
2. Shor, P. Algorithms for Quantum Computation: Discrete Logarithms and Factoring. Proceedings of the 35th Annual Symposium on Foundations of Computer Science. IEEE Computer Society Press, 1994,124-134. (http://xxx.lanl.gov/pdf/quant-ph/9508027).
3. Barenco, A., C. Bennett, R. Cleve, et al. Elementary Gates for Quantum Computation. *Physical Review Letters* A, 52, 1995, 3457.
4. Vedral, V., A. Barenco and A. Ekert. QuantumNetworks for Elementary Arithmetic Operations. (http://xxx.lanl.gov/pdf/quant-ph/9511018).
5. Benett, C. Logical Reversibility of Computation-*IBM Journal of Research and Development,* 1973,17,525-532. (http://www.research.ibm.com/journal/rd/176_ibmrd1706G.pdf).
6. Dirac, P. A. M. The Principles of Quantum Mechanics. Oxford University Press, Oxford, 1947.

Additional Sources

7. Lenstra, H., H. Lenstra, Jr., M. Manasse, et al. The Number Field Sieve. Proceedings of the 22nd Annual ACM Symposium on Theory of Computing, ACM, New York, 1990, 564-572.
8. Pavlov, V., H. Turlakov and K. Boyanov. Quantum Computation and Quantum Computers (Квантово изчисление и квантови компютри).-*Engineering Sciences*, XLII, 2005, 2, 5-28.
9. Deutsch, D. Quantum Computational Networks. Proceedings of the Royal Society, Ser. A, 425, 1989, 73-90.
10. Benioff, P. The Computer as a Physical System: Microscopic Quantum Mechanical Hamiltonian Model of Computers as Represented by Turing Machines.-*Journal of Statistical Physics*, 22, 1980, 563-591.
11. Feynman, R. Simulating Physics with Computers International Journal of Theoretical Physics, 21, 1982,46-488.
12. Deutsch, D. and R. Jozsa. Rapid Solution of Problems by Quantum Computation.-Proceedings of the Royal Society, Ser. A, 439, 1992, pp. 553-558.
13. Landauer, R. Irreversibility and Heat Generation in the Computing Process. *IBM Journal,* 1961, 183-191. (http://www.research.ibm.com/journal/rd/053/ibmrd0503C.pdf).
14. Eisert, J. and M. M. Wolf. *Quantum Computing.* (http:xxx.lanl.gov/pdf/quant-ph/0401019).
15. DiVincenzo, D. *Two-bit Gates are Universal for Quantum Computation.* (http://xxx.lanl.gov/pdf/quant-ph/9407022).
16. Barenco, A. *A Universal Two-bit Gate for Quantum Computation.*(http://xxx.lanl.gov/pdf/quant-ph/9505016).
17. Deutsch, D., A. Barenco and A. Ekert. *Universality in Quantum Computation.* (http://xxx.lanl.gov/pdf/quant-ph/9505018).
18. Deutsch, D. and A. Ekert. *Machines, Logic and Quantum Physics* (http://xxx.lanl.gov/pdf/math.HO/9911150).

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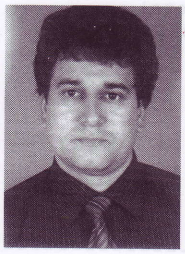

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