Grid Technologies

Emerging from Distributed Architectures to Virtual Organizations

Advances in Management Information Series

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Dedication

Dedicated with respect to the memory of Professor David John Evans of Loughborough University, England.
We shall never forget him and he will always be with us.

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The preparation of such a comprehensive text would not have been possible without the support and encouragement of so many individuals. It is always a major undertaking, as science and technology rarely sit still long enough so to be able to collect significant research activities within an area.

First and foremost, we wish to thank all the distinguished scientists who kindly consented to contribute to this volume, who are some of the very same people who are creating those scientific changes. To them all, we are deeply indebted and it is indeed an honour to include our works with theirs. We trust that this collection will give a good overview of current thinking on these main topics and will be valuable to all who take an interest in these fields.

We wish to record our sincere thanks to Prof. C. A. Brebbia and his colleagues at the Wessex Institute of Technology, for their help in editing this book.

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Finally, we would like to extend our thanks to the production staff of WIT Press for their efforts towards the timely production of this book.

The Editors
2006

Contents

Foreword

The Grid will be the major direction in the future that will provide an environment for a virtual global society in business, government, science and entertainment.

This book attempts to highlight certain topics in this area. Chapters cover subjects like visualization services, architecture, security, infrastructure, workflow management and quality of services. In addition, there are some chapters that introduce beginners to the field to the basic principles of Grid Computing.

In an emerging technology like Grid Computing, it is hard to foresee what is essential in the sense that it will last. I believe that the editors have chosen the subjects that will fulfill this requirement.

This book is organized into two parts. In the first part "Theory and Services" , there are eight chapters.

The first chapter by P. Heinzlreiter and D. Kranzlmueller presents an overview of state-of-the-art techniques and solutions for grid based visualization.

Chapter Two, by B. Volckaert *et al.*, investigates the use of network monitoring information, in order to produce Grid job schedules.

Chapter Three, by W. Wu *et al.*, presents a scalable, integrated and service-oriented collaboration system, which can provide video conferencing services to heterogeneous endpoints.

Chapter Four, by G. Fox *et al.*, reviews efforts of the authors to built science application Grids, using Web Service Architectures.

Chapter 5, by A. Chazapis *et al.*, focuses on the data management problem and elaborates on how future grid deployments can exploit modern peer-to-peer architectures and related algorithms.

Chapters Six and Seven, by H. Liu and X. Lin, concern grid security issues.

The final chapter, by M. N. Vafopoulos *et al.*, describes some interesting ideas for providing an integrated bundle of web services and processing power resources to form a personal grid e-workspace.

In the second part, "Middleware and Grid Computations", eight chapters are included. They basically introduce the reader to topics of general interest in Grid Computing.

The first chapter, by L. Wang *et al.*, studies the concepts of workflow systems and workflow management, as well as identifying and discussing major relevant research issues and technological challenges.

In chapter Two, by J. Morrison *et al.*, a fledging Grid Operating System, Web

Com-G, is proposed, which is designed to provide independent service access through interoperability with existing middleware.

Chapter Three, by G. von Laszewski and M. Hategan, introduces a number of grid abstractions that make the development of Grid Middleware easier.

Chapter Four, by E. M. Karanikolau *et al.*, is an introduction to Grid Computing.

Chapter Five, by M. P. Bekakos *et al.*, proposes a pilot Grid platform, for high performance internet computations.

Chapter Six, by Y. Li and M. Mascagni is an overview of Grid-based Monte Carlo Computing.

Chapter Seven, by M. Ch. Karra and M. P. Bekakos, investigates a network of systolic arrays solving a linear system, as well as its mapping on a small or large-scale basis.

The last chapter, by Z. Luo *et al.*, describes issues for shifting high performance computing to meeting commercial business computing requirements.

I believe that the editors have succeeded in choosing subjects that are of current interest in the area of Grid Computing and will become major issues in the future.

G. Papakonstantinou
Athens, 2006

Preface

Purpose and goals

This book is structured around six central themes, which aim to provide a more detailed picture of the expected purpose, shape, and architecture of future grid systems. The themes are as follows: The need for computational grids, the types of applications that grids will be used for, the potential grid users, the grid utilization, the building of a grid, and what kind of problems must be solved to make grids commonplace.

This book provides an overview of each of these issues in corresponding chapters through a state-of-the-art survey of Grid technologies from the aspect of provided web services, middleware, applications of processor network architectures and of various distributed computational methods.

Grid Computing denotes an approach to utilize distributed resources that are not subject to centralized control. This approach fulfils computing requirements arising within the context of current high-performance computing applications, especially in the field of computational science and engineering.

This idea is analogous to an electric power network (grid), where power generators are distributed, but the users are able to access electric power without any concern regarding the source of energy or its location.

Current Grid enabling technologies consist of stand-alone architectures. A typical architecture provides middleware access to various services at different hierarchical levels. Computational Grids enable the sharing, selection and aggregation of a wide variety of geographically distributed computational resources (such as supercomputers, clusters of computers, storage systems, data sources, instruments, people, etc.) and present them as a single, unified resource for solving large-scale computations and data intensive computing applications (e.g., engineering problems, molecular modeling for drug design, brain activity analysis, high energy physics, etc.).

Grid Computing is a new emerging research area aiming to promote the development and advancement of technologies that provide seamless and scalable access to wide-area distributed resources.

Because of the increasing interdependence of the research activities in these major areas of web services and distributed computations, we felt it not only timely, but also important to produce this reference and study text. The editors believe that the contributions in this book provide a valuable pointer to the research issues in this area.

This book consists of sixteen self-contained chapters, each authored by experts who have actually performed the implementations covered in their respective chapters. The authors provide results of their work, which in some cases are as yet unpublished.

The content is aimed at graduate/postgraduate students and researchers working in the area of grid technologies. It can also be used by educators at these levels to illustrate the use and methods of grid computing. Because the mathematical analyses are lucid it can also serve as a good reference book for the practitioners in this field. We hope you will find it of value.

Organization of the book

Grid technologies are a growing scientific area with the potential to offer virtually unlimited computational power, provided that effective software and application techniques and tools can be produced to be able to take advantage of such potential. Because of the importance of Grid computing for the advancement of computer technology, a great research and development effort is underway. This is reflected in the increasing amount of technical literature that is being produced and the number of papers that are currently being published. An attempt to gain a comprehensive and detailed understanding of the state-of-the-art and the current technological trends in the field of Grid computing by studying the technical literature in all its breadth and depth is both difficult and time-consuming.

Through the collective efforts of some 48 authors and co-workers, this book examines the realization and use of various Grid Computing methodologies for solving scientific and engineering problems. It contains a significant amount of expository and explanatory material, which is structured in a modular fashion of self-standing chapters. The book is divided into two parts, each surveying several subjects of interest to the scientific community in the areas of web services, middleware, distributed and grid computing.

Part One: Theory and services

Part One contains a collection of articles arranged into eight chapters and is mainly concerned with the visualization services on the grid, videoconferencing, building a Grid of Grids, replica management services on the Grid, computer and Grid security, trustworthy Grids, and grid e-workspace.

In Chapter 1, P. Heinzlreiter and D. Kranzlmueller present an overview of state-of-the-art techniques and solutions for grid-based visualization. A special focus is put on the Grid Visualization Kernel (GVK), which is a grid middleware extension providing visualization services for grid-based applications by exploiting the computational power of the grid for the execution of the visualization task. It aims at being flexible regarding the input data format, the output device and the rendering algorithms applied.

In Chapter 2, B. Volckaert, *et al.* investigate the use of network monitoring information in network aware algorithms to produce Grid job schedules. Network awareness allows for more intelligent scheduling decisions, since accurate figures on the speed at which the required job input and output data can be transferred between the different Grid resources allow for a precise prediction of job running times.

In Chapter 3, W. Wu, *et al.* present a scalable, integrated and service-oriented collaboration system, namely Global Multimedia Collaboration System, based on the XGSP collaboration framework and NaradaBrokering messaging middleware. This system can provide videoconferencing services to heterogeneous endpoints such as H.323, SIP, Access Grid, RealPlayer as well as cellular phones.

In Chapter 4, G. Fox, *et al.* investigate the building of science application Grids using Web Service Architecture principles. They review several aspects of the problem, including a) designing and integrating families of Grid Web Services; b) Grid messaging substrates, and c) developing client ("requester agent") managing environments such as computing Web portals. The merger of Grid and Web Service standards first introduced by the Open Grid Service Architecture (OGSA) opened up the possibility of creating and integrating disparate Grid families that formerly used incompatible technologies.

In Chapter 5, A. Chazapis, *et al.* investigate the requirements of a Grid-centric, replica-based data storage and retrieval infrastructure and present the current trends and implementations and elaborate on how future architectures will be able to capitalize on peer-to-peer technologies in order to achieve even higher levels of scale, without the need of deploying special data management servers.

In Chapter 6, H. Liu and X. Lin, present a glimpse on the fundamentals of computer and grid security, including the semantics of security and threat, policy and mechanism, cryptography and checksum, key management, cryptographic key infrastructure, stream cipher, block cipher, TLS, IPsec, GSI and CAS, grid security services, web services specifications and standards, risk analysis and threat model, etc. The material focuses on the theoretical aspects of these building blocks that can be employed to build the trustworthy grids.

In Chapter 7, H. Liu and X. Lin, focus on the topics of trust negotiation and multiparty joint authentication. A trustworthy grid can be defined as a grid to provide coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations with a specified, understood secure level. Among all kinds of building blocks for a trustworthy grid, trust negotiation and multiparty semantic enrich the innovation space of security greatly. Trust negotiation deals with concepts such as formulating security policies and credentials, determining whether particular sets of credentials satisfy the relevant policies, and deferring trust to third parties. Multiparty semantic means multiparty interaction in grids. Intuitively, multiparty joint authentication can be comprehended as bringing the paradigm of peer-to-peer into Kerberos.

In Chapter 8, M. Vafopoulos, *et al.* consider that semantic web technologies and grid computing are emerging as the enabling infrastructure for the next decades, because they are providing a unified way for managing distributed computing, data and human resources. The fundamental challenge along this way is to provide an integrated bundle of user-centric web services coupled to processing power resources, namely a personal grid e-workspace (g-work) to every citizen. G-work is another step towards Ámbient Éntelligence's (AmI) environment vision.

Part Two: Middleware and grid computation

Part Two contains a collection of articles arranged into eight chapters and is mainly concerned with the study and exploitation of middleware and Grid computation methodologies.

In Chapter 9, L. Wang, *et al.* firstly study the concepts of workflow, workflow systems and workflow management. The current status of workflow management for Grid computing is investigated, including models, and languages of popular workflow management systems in computational Grids. In addition to this, major research issues and technological challenges are identified and discussed. The chapter concludes that it is essential to address these problems for Grid workflow to be pervasively accepted and used.

In Chapter 10, J. P. Morrison, *et al.* discuss the fact that Grid computing will be an important technology in the near- to long-term (indeed it can be credibly argued that it is already a very important technology to a select few), and that widespread acceptance will depend on making that technology easily accessible to general exploitation. In practice, this will not only involve interoperability and inclusiveness of key features, but most importantly, it will require non-specialists to be familiar with constructing grid-independent applications that run efficiently on the dynamic architecture that constitutes the Grid. The original problems of programming parallel and distributed systems still hold true: they are notoriously hard to program, since programmers usually have responsibility for synchronizing processes and for resource management. Solutions must be developed to free programmers from the low level details which give rise to these problems. In effect, grid programming environments must evolve to a point where grid (and, in general, parallel) programs are freed from architecture details such as data locality, machine availability, inter-task synchronization, communication topologies, task load-balancing, and fault tolerance – in the same manner as present day sequential programmers are freed from explicit memory management, disk access protocols and process scheduling. At that point in the evolution of the Grid, the grid middleware will adopt the character of a grid operating system and many, if not all of the issues that make grid programming difficult, will migrate out of grid application programs. When this is achieved, the vision of hiding the Grid will have been realized and exploitation of the technology can begin in earnest.

WebCom-G is a fledgling Grid Operating System, designed to provide independent service access through interoperability with existing middlewares. It offers an expressive programming model that automatically handles task synchronization: load balancing, fault tolerance, and task allocation are handled at the WebCom system level, without burdening the application writer. These characteristics, together with the ability of its computing model to mix evaluation strategies to match the characteristics of the geographically dispersed facilities and the overall problem-solving environment, make WebCom a promising grid middleware candidate.

In Chapter 11, G. von Laszewski and M. Hategan introduce a number of Grid abstractions that make the development of Grid middleware independent tools possible and allow for the integration of a number of commodity tools. Their vision is implemented through an integrated approach based on a layered architecture that attempts to bridge the gap between Grid middleware and scientific applications. Their abstractions include specialized services, a Grid workflow engine and language, and Grid faces which are graphical abstractions that can be employed in science portals and standalone applications.

In Chapter 12, E. M. Karanikolaou, *et al.* discuss how the distributed environment that allows the sharing and common use of computing power, storage resources and others (e.g., sensors), with the help of a middleware, is called a Grid and is considered more and more to be the next phase of distributed computing.

One of the most popular middlewares today is the Globus Toolkit, which is a collection of software packages created for Grid deployment. Such middlewares aim to connect widely spread systems, involving supercomputers, storage systems, data sources, as well as special devices such as scientific instruments and visualization devices, effectively.

Because the Web is an information exchange service through the Internet, a Grid is a computing and storage distribution service through the Internet, which finally intends to turn the world's computers network into a unified computational resource.

In Chapter 13, M. P. Bekakos, *et al.* discuss how current distributed computing approaches do not provide a general resource-sharing framework that addresses VOs requirements. Grid technologies distinguish themselves by providing this generic approach to resource sharing.

The pilot Grid platform for high performance internet computations introduced in this chapter consists of two clusters of eight interconnected computers, each using the Globus middleware. The algorithms can be executed either on one unique platform of sixteen interconnected computers using the MPICH program or on the pilot Grid platform of the two clusters. The MPICH program is either used in a Linux or Windows environment.

In Chapter 14, Y. Li and M. Mascagni survey research directions associated with Grid-based Monte Carlo computations. In particular, they focus both on Monte Carlo Grid computing paradigms and the special aspects of Monte Carlo applications that enable the use of specialized and highly efficient techniques. They discuss the general principles of Grid-based Monte Carlo methods, the dynamic *bag-of-tasks* model for executing many Monte Carlo applications on the Grid, random number generation as it pertains to the Grid, and application trustworthiness enforcement and performance improvement taking advantage of the inherent characteristics of Monte Carlo methods. They also discuss applying Grid-based Monte Carlo to various problems in Monte Carlo integration and Markov Chain Monte Carlo, which are drawn from various branches of simulation in science and engineering.

In Chapter 15, M. Ch. Karra and M. P. Bekakos investigate a network of systolic arrays for solving a linear system with the use of the *Quadrant Interlocking Factorization (butterfly)* method. A Grid infrastructure of such networks mapped on a reconfigurable hardware platform, i.e. FPGA, could be then organized on a small or large-scale basis. The transition though, from a Grid of general-purpose computers to a Grid where reconfigurable hardware is used is not self-evident. A number of certain issues should be confronted beforehand and only then the remote configuration of FPGAs would become possible; thus, a transition from the "micro" grid infrastructure described in the chapter, to a larger infrastructure with alternative remote resources would become feasible.

In Chapter 16, Z. Luo, *et al.* discuss that the vision of Grid computing is to bring together heterogeneous resources and to allocate them efficiently to applications. As the focus of Grid research and development is shifting from high performance computing to meeting commercial business computing requirements, they see a bright future for Grids. The Grid vision of resource virtualization is being well accepted. However, it will still take several years before commercial grid computing matures as the popular enabling means for business applications. Challenges lie on both business and technical sides with issues such as Grid standards maturation, software ready-ness, and market cultivation beyond traditional high performance computing.

The Editors
2006