

# Emerging Technologies for MultiCluster/Grid Computing

Rajkumar Buyya

*rajkumar@csse.monash.edu.au*  
*Monash University, Melbourne, Australia*

Mark Baker

*Mark.Baker@computer.org*  
*University of Portsmouth, UK*

## Abstract

The growing popularity of the Internet along with the availability of powerful computers and high-speed networks as low-cost commodity components is changing the way we do computing. The emergence of two computing paradigms, "cluster computing" and "global computing" (Grid computing), is making developers rethink the way they design and implement their applications. The emerging technologies are enabling the coupling of a wide variety of geographically distributed resources such as desktop computers, clusters, storage systems and scientific instruments, and allowing them to be used as a single unified resource and thus forms what is popularly known as a Grid. In this tutorial we raise a number of open issues that the Grid community of researchers and developers need to address. Special emphasis will be placed on create a Grid of clusters-computing on multiple clusters geographically distributed across the campus, nation, or world.

We first discuss a number of social and architectural issues that are guiding the design of the next generation of Internet technologies and applications. We then describe some major international efforts in developing self-organising Grid software systems and applications both in academic, research and commercial settings. We then go onto to present some economics issues in Grid computing that are being developed, as well as the results of some experiments on wide-area high-throughput computing across the Internet. We conclude the tutorial by highlighting sociological and intellectual implications of this new Internet computing paradigm and its impact on the marketplace.

*Rajkumar Buyya is a Research Scholar at the School of Computer Science and Software Engineering, Monash University, Melbourne, Australia. He was awarded Dharma Ratnakara Memorial Trust Gold Medal for his academic excellence during 1992 by Kuvempu/Mysore University. He is co-author of books: Mastering C++ and Microprocessor x86 Programming; and recently, he has edited a two volume book on High Performance Cluster Computing: Architectures and Systems (Vol. 1); Programming and Application (Vol.2) published by Prentice Hall, USA. He served as Guest Editor for the special issues of international journals: Parallel and Distributed Computing Practices, Informatica: An International Journal of Computing and Informatics, and Journal of Supercomputing.*

*Rajkumar is a speaker in the IEEE Computer Society Chapter Tutorials Program. Along with Mark Baker, he co-chairs the IEEE Computer Society Task Force on Cluster Computing. He has contributed to the development of HPCC system software environment for PARAM supercomputer developed by the Centre for Development of Advanced Computing, India.*

*Rajkumar conducted tutorials on advanced technologies such as Parallel, Distributed and Multithreaded Computing, Client/Server Computing, Internet and Java, Cluster Computing, and Java and High Performance Computing at international conferences. He has organised/chaired workshops, symposiums, and conferences at the international level in the areas of Cluster Computing and Grid Computing. He also serves as a reporter for Asian Technology Information Program, Japan/USA. His research papers have appeared in international conferences and journals. His research interests include Programming Paradigms and Operating Environments for Parallel and Distributed Computing.*

***Mark Baker** started working in the field of High Performance Computing at Edinburgh University (UK) in 1988. In Edinburgh he was involved in the development of parallel linear solvers on a large Transputer-systems using Occam. From 1990 until 1995 Mark was a project leader of a group at the University of Southampton (UK). This group was involved in developing and supporting environments and tools for a range of parallel and distributed systems. It was whilst at Southampton that Mark started to actively investigate and research software for managing and monitoring distributed environments. In 1995 Mark took up a post as Senior Research Scientist at NPAC, Syracuse University (USA). Whilst at NPAC Mark researched and wrote the widely cited critical review of the Cluster Management Systems. At Syracuse Mark worked on a range of projects involving the major HPC groups and Labs. in the US. It was during this period that he worked closely with Prof. Geoffrey Fox on a variety of cluster and metacomputing related projects.*

*Since 1996, Mark has been a Senior Lecturer in the Division of Computer Science at the University of Portsmouth. At Portsmouth Mark lectures on network architectures, client/server programming and open distributed systems. Mark's current research is focused on the development of tools and services for PC-based distributed systems. Mark also tracks international metacomputing efforts and is involved with Java Grande and the definition of a Java interface to MPI.*

*Mark has written a number of articles and papers on Cluster and Grid Computing. Mark is co-chair of the IEEE Computer Society Task Force on Cluster Computing (TFCC) and is currently a visiting Senior Research Scientist at Oak Ridge National Lab., USA.*

*Mark is on the international editorial board of the Wiley Journal, Computation and Concurrency: Practice and Experience and regularly reviews papers for many journals in his field, including IEEE Computer and Internet Computing. Mark is the editor of the Grid Computing section of the IEEE CS on-line magazine DS-Online. Mark has given conference tutorials at HPDC (1999 and 2000), EuroPar 2000, Cluster 2000 and SC 2000. A full list of Mark's recent tutorials can be found at <http://www.dcs.port.ac.uk/~mab/Tutorials/>.*