Grid Computing and Distributed Systems Laboratory and the Gridbus Project

Annual Report - 2006

By

Dr. Rajkumar Buyya

Associate Professor and Reader

Department of Computer Science and Software Engineering

The University of Melbourne, Australia

Director's Message

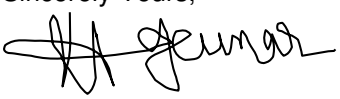
I am pleased to report on the key activities and outcomes of Grid Computing and Distributed Systems (GRIDS) Laboratory at the University of Melbourne, Australia during the academic year 2006, which has been a significant year for GRIDS Lab and its members. The GRIDS Lab continues to be one of the leading and innovative research groups internationally in the area of Grid computing. The highlights of research activities and outcomes in 2006 are given below:

- The Lab successfully completed (a) two ARC (Australian Research Council) Discovery projects and (b) two ARC e-Research projects with outstanding research outcomes.
- Members of GRIDS Lab have authored over 30 publications, which include 6 journal papers, 15 conference papers, and 5 edited conference proceedings.
- The Lab's flagship Gridbus Project has released "open source" Grid middleware technologies including the Grid Service Broker, GridSim, and Gridscape, which are used by several researchers and users in academia and industries around the globe.
- Members have presented over 20 invited talks that include 5 keynote talks delivered at international conferences held in South America (Chile), Middle East (Iran) and Asia (India and Malaysia).
- The Lab successfully hosted research activities of over 20 scholars: 8 research students (most of them were PhD students), 3 Research Fellow (at PostDoc level), 3 Software Engineers, and couple of Masters/honours students. Two research students have graduated, one with a Ph.D., and the other with a Masters by research degree.
- The Lab Director has been recognised for his outstanding contribution to R&D in the Dept. of Computer Science and Software Engineering though "Research Excellence Award."
- The Lab housed several (short and long term) international visitors who are (a) academic researchers from USA, New Zealand, Germany, Japan, and India; and (b) visiting PhD students from Europe.
- The Lab contributed towards the establishment of Australia National Grid (APACGrid) by leading the development of Grid portal for Molecular Docking for Drug Discovery.
- Members of the Lab have led by community efforts by (a) involving in the organisation of conferences (Grid 2006, Span; SBAC-PAD 2006, Brazil; GCC 2006, China), (b) serving on the Steering Committee of CCGrid 2006 and SC 2006, and (c) Chairing the IEEE Computer Society's Technical Committee on Scalable Computing (TCSC).

The Lab has secured funding for future research (2007-2010) from ARC and DEST (Department of Education, Science, and Training) through their Discovery Project and International Science Linkage programmes respectively. As a result, we have established strategic linkages with researchers in Europe (CoreGrid and CatNets projects), Asia (China and India), and USA.

The Lab is always looking for talented, motivated, and dedicated students and researchers to join its team. If you are interested in working or collaborating with us, please feel free to contact me.

Sincerely Yours,



Associate Professor Rajkumar Buyya, PhD
Director, Grid Computing and Distributed Systems (GRIDS) Lab
Department of Computer Science and Software Engineering
The University of Melbourne, Australia
Email: raj@csse.unimelb.edu.au
Web: http://www.gridbus.org

The Team

Director:

- Dr.Rajkumar Buyya, Associate Professor and Reader

Research Staff:

- Dr. Srikumar Venugopal
- Dr. Kyong Hoon Kim
- Dr. Chao Jin
- Dr. Tianchi Ma
- Dr. James Broberg
- Mr. Krishna Nadiminti
- Mr. Hussein Gibbins
- Mr. Xingchen Chu

PhD Students

- Ms. Jia Yu
- Mr. Anthony Sulistio
- Mr. Chee Shin Yeo
- Mr. Rajiv Ranjan
- Mr. Marcos Assunção
- Mr. Marco A. S. Netto

Masters by Research Students

- Mr. Martin Placek
- Mr. Al-Mukaddim Khan Pathan
- Mr. Md Mustafizur Rahman

Collaborators

- Colleagues holding research grants with the Director
- International Visitors
- Many collaborators involved in extending and using the Gridbus software

Competitive Grants Funded Projects and Programs

Australian Research Council (ARC)

- M. Sevior and R. Buyya, *"The Development of Data Grids for High Energy Physics"*, Discovery Project, Australian Research Council (ARC), Australia, 2004-2006. Amount: $510,000.
- R. Buyya and A. Harwood, *"Economic Scheduling for Efficient Management of Clusters and their Cooperative Federation"*, Discovery Project, Australian Research Council (ARC), Australia, 2004-2006. Amount: $150,000.
- C. Kepert (1), D. Abramson (2) et. al., R. Buyya (9) et. al., P. Turner (43), et. al., and A. Zomaya (50), "Molecular and Materials Structure Network", ARC Research Network Program, Australian Research Council (ARC), Australia, 2004/05 to 2008/09. Amount: $1,500,000.
- M. Palaniswami (1) et. al., R. Buyya (6) et. al., R. Evans (14) et. al., R. Kotagiri (21), et. al., and Y. Attikiouzel (50), "ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing", ARC Research Network Program, Australian Research Council (ARC), Australia, 2004/05 to 2008/09. Amount: $2,250,000.
- G. Egan, R. Buyya, I. Mareels, R. Kotagiri, and A. Toga, *"Development of e-Research Tools for an MRI Grid Computing Facility"*, e-Research Initiative, Australian Research Council (ARC), Australia, 2005-2006. Amount: $80,000.
- P. Harris, A. Lonie, R. Buyya, S. Thomas, P. Hunter, W. Appelbe, *"eResearch Grid Environment for Integration of Distributed Kidney Models and Resources"*, e-Research Initiative, Australian Research Council (ARC), Australia, 2005-2006. Amount: $124,422.

Commonwealth of Australia - CRC (Cooperative Research Centre) Grant:

- R. Buyya was part of a team (as one of the contributed staff members from the Universities sector/The University of Melbourne) that successfully bid for eWater CRC led by Prof. Gary Jones. CRC received $ 40.25millon funding from Australian Government administered through the Department of Education, Science and Training (DEST), 2005-2012.
- R. Buyya (project manager) and team, *The Utility Grid Project: Autonomic and Utility-oriented Global Grids for Powering Emerging E-Research Applications*, International Science Linkages, Department of Education, Science & Training, Australia, 2006-2009. Amount: $592,875.

Industry and Melbourne University

- B. Smith, R. Buyya, and K. Branson, "*BioGrid: Web and Grid Services Enabled Molecular Docking for Drug Discovery*", APAC Grid Program, Australian Partnership for Advanced Computing (APAC), Canberra, Australia, 2004-2006. Amount: $157,500.
- R. Buyya, Chief Investigator, "*.NET Educational and Research Initiatives*", Microsoft Corporation, Australia, 2006. Amount: US$20,000.
- R. Buyya, Chief Investigator, "Tewkesbury Fellowship - Hosting Research Visit of Prof. Manish Parashar, Rutgers: The State University of New Jersey, USA", Faculty of Engineering, The University of Melbourne, 2006. Amount: $4000.

European Union Projects Grant:

- R. Buyya was part of a team and the University of Melbourne as an international partner in an European Union funded project led by Prof. Denis Caromel (INRIA, France), "Grids Programming with Components (GridComp), 2006-2009. Amount: € 1,928,278.00.

Reports on Two ARC Projects Completed in 2006

ARC Discovery Project (2004 -2006): DP0452632 Report
Investigators: M. Sevior and **R. Buyya** (CI)
Title: The Development of Data Grids for High Energy Physics

Data Grids have developed worldwide interest as a means of enabling geographically separated groups to collaborate and share data and computing resources. Their use is particularly important to Australians. High Energy Physics (HEP) has been, and will continue to be a test-bed for these technologies. Through our involvement with the state-of-the-art experiments at BELLE and ATLAS, this DP project aimed to participate in the World-wide Data Grid research and development effort and deploy novel techniques to significantly enhance their usefulness to Australians. Towards this goal, the project has made substantial progress in algorithms and technology development, publications, and international collaborations.

We have setup Australian Belle Data Grid platform and deployed the Belle application on resources based at APAC National Grid, the Victorian Partnership of Advanced Computing (VPAC) and the University of Melbourne. The Storage Resource Broker (SRB) installation provides a federated storage infrastructure for transferring data between the KEK facility in Japan and Australian storage facilities such as the APAC mass storage facility. This platform has been used in Grid middleware R&D and Belle data analysis.

We have developed the Gridbus Grid Resource Broker (GRB) to support a range of HEP Data Grid requirements that provides capabilities for creation and deployment of HEP applications. Our Grid resource broker is able to discover suitable compute and data resources, schedule and perform coordinated execution of jobs, handle failures, seamlessly access distributed data using SRB and retrieve results. We have also developed Gridbus broker portlets to enable creation of application-specific Web-portals. We have extended our GridSim toolkit to support simulation of Data Grids and advanced networks, which has been used in developing and evaluating optional Data Grid scheduling and replication algorithms on global Grids. We have also applied our Grid technologies to other e-Research applications in Neuroscience and Life Sciences domains. In addition, we are actively contributing to the development of APACGrid (Australian National Grid) program. The GridSim toolkit with DataGrid extensions is used by researchers in many countries to carry out investigation on resource management in grids.

During the course of the project, we have authored several high quality research papers (4 book chapters, 7 journal papers, and 20 conference papers) and published them in peer-reviewed and high impact journals and conferences. The CI (Buyya) has presented several invited talks in which results of this project are highlighted. For instance, he presented in conferences (keynote at IEEE International Conference on Peer-to-Peer Computing, Sweden), universities (University of Southern California and University of Illinois, Chicago) and industries (HP Labs, IBM and Singapore Computer Systems).

Selected Publications

- A. Sulistio, C. S. Yeo, and R. Buyya, A Taxonomy of Computer-based Simulations and its Mapping to Parallel and Distributed Systems Simulation Tools, *Software: Practice and Experience*, Volume 34, Issue 7, Pages: 653-673, Wiley Press, USA, June 2004.
- S. Venugopal, R. Buyya, and L. Winton, *A Grid Service Broker for Scheduling Distributed Data-Oriented Applications on Global Grids*, Proceedings of the 2nd International Workshop on Middleware for Grid Computing (part of Middleware 2004, Toronto, Canada, October 18, 2004), ACM Press, 2004, USA.
- R. Buyya, D. Abramson, and S. Venugopal, The Grid Economy, *Proceedings of the IEEE*, M. Parashar and C. Lee (eds.), Volume 93, Issue 3, 698-714, pp, IEEE Press, New York, USA, March 2005.
- S. Venugopal and R. Buyya, *A Deadline and Budget Constrained Scheduling Algorithm for eScience Applications on Data Grids*, 6th International Conference on Algorithms and Architectures for Parallel Processing (Springer Verlag Press, Germany), Oct 2-5, 2005, Melbourne, Australia.
- T. Ma and R. Buyya, *Critical-Path and Priority based Algorithms for Scheduling Workflows with Parameter Sweep Tasks on Global Grids*, Proceedings of the 17th International Symposium on Computer Architecture and High Performance Computing (IEEE CS Press, USA), Oct. 24-27, 2005, Rio de Janeiro, Brazil.
- J. Yu, S. Venugopal, and R. Buyya, A Market-Oriented Grid Directory Service for Publication and Discovery of Grid Service Providers and their Services, *The Journal of Supercomputing*, Volume 36, No. 1, Pages:17-31, ISSN: 0920-8542, Springer Science+Business Media, Berlin, Germany, April 2006.
- S. Venugopal, R. Buyya and L. Winton, A Grid Service Broker for Scheduling e-Science Applications on Global Data Grids, *Concurrency and Computation: Practice and Experience*, Volume 18, Issue 6, Pages: 685-699, Wiley Press, New York, USA, May 2006.
- S. Venugopal, R. Buyya, and K. Ramamohanarao, A Taxonomy of Data Grids for Distributed Data Sharing, Management and Processing, *ACM Computing Surveys*, Volume 38, No. 1, Pages:1-53, ISSN 0360-0300, ACM Press, New York, USA, March 2006.
- S. Venugopal and R. Buyya, *A Set Coverage-based Mapping Heuristic for Scheduling Distributed Data-Intensive Applications on Global Grids*, Proceedings of the 7th IEEE/ACM International Conference on Grid Computing (IEEE CS Press, USA), Sept. 28-29, 2006, Barcelona, Spain.

ARC Discovery Project (2004 -2006): DP0452102 Report
Investigators: R. Buyya (CI) and A. Harwood
Title: Economic Scheduling for Efficient Management of Clusters and their Cooperative Federation

The goal of this ARC DP Project research is to investigate computational economy based scheduling policies for allocation of resources based on the user's QoS (Quality of service) needs within clusters; and an infrastructure for logical coupling of multiple clusters for resource sharing based on policies defined by their owners. Towards this goal, the project has made substantial progress: algorithms and technology development, publications (listed below), outreach, and international collaborations.

This project has developed: (1) a taxonomy and architectural framework for QoS cluster scheduling that supports scalability and inter-cluster cooperative federation, (2) a computational economy methodology for clusters and cooperation federation of clusters, (3) scheduling algorithms for different application models and different pricing models, and (4) transparent load balancing and sharing across inter-cluster federation based on user-defined QoS requirements and sharing policies.

We have enhanced Alchemi desktop clusters/enterprise grid platform and developed interfaces required for implementing user-level schedulers. This platform is being leveraged to implement user-level scheduler supporting economy and QoS based scheduling in intra and inter-cluster systems. In addition, we have developed an environment for coupling distributed clusters (managed by Alchemi) and federate them using scalable/p2p publish and subscribe system.

Alchemi software partially supported by this project has been utilised by many research and commercial organisations. For example, (a) CSIRO or eWater CRC has used it in distributed execution of their catchment modelling toolkit and (b) Friedrich Institute for Medical Research in Switzerland has used it in gene data processing; The research work of Columbia University (USA) and IBM T.J. Watson on "Effecting Runtime Reconfiguration in Managed Execution Environments" is carried out using our Alchemi in .NET environment

During the course of the project, we have authored several high quality research papers (3 book chapters, 5 journal papers, and 17 conference papers) and published them in peer-reviewed and high impact journals and conferences. In addition, the CI (Buyya) has presented several invited talks in which results of this project are also highlighted. For instance, he presented in conferences (keynote at Business Grid Symposium, Korea), universities (University of Southern California and Nottingham University) and industries (IBM, Infosys, Satyam).

Selected Publications

- J. Sherwani, N. Ali, N. Lotia, Z. Hayat, and R. Buyya, Libra: A Computational Economy based Job Scheduling System for Clusters, *Software: Practice and Experience*, 34(6), 573-590pp, Wiley Press, USA, May 2004.
- A. Apon, R. Buyya, H. Jin, and J. Mache, Cluster Computing in the Classroom and Integration with Computing Curricula 2001*, IEEE Transactions on Education*, 47(2), 188-195pp, IEEE Press, USA, May 2004.
- G. Cheliotis, C. Kenyon, and R. Buyya, Lessons from Finance for Commercial Sharing of IT Resources, *Peer-to-Peer Computing: Evolution of a Disruptive Technology*, R. Subramanian and B. Goodman (eds), 244-264pp, ISBN: 1-59140-429-0, Idea Group Inc., Hershey, PA, USA, 2005.
- A. Luther, R. Buyya, R. Ranjan, and S. Venugopal, Peer-to-Peer Grid Computing and a .NET-based Alchemi Framework, *High Performance Computing: Paradigm and Infrastructure*, L. Yang and M. Guo (eds), pp.403-429, ISBN: 0-471-65471-X, Wiley Press, New Jersey, USA, June 2005.
- R. Ranjan, R. Buyya and A. Harwood, *A Case for Cooperative and Incentive-Based Coupling of Distributed Clusters*, Proc. of the 7th IEEE International Conference on Cluster Computing (IEEE CS Press, Los Alamitos, CA, USA), Sept. 27 - 30, 2005, Boston, USA.
- C. S. Yeo and R. Buyya, *Managing Risk of Inaccurate Runtime Estimates for Deadline Constrained Job Admission Control in Clusters*, Proceedings of the 35th International Conference on Parallel Processing (IEEE CS Press, Los Alamitos, CA, USA), August 14-18, 2006, Columbus, Ohio, USA.
- M. Placek and R. Buyya, *Storage Exchange: A Global Trading Platform for Storage Services*, Proceedings of the 12th International European Parallel Computing Conference (Springer-Verlag Press, Berlin, Germany), Aug. 29-Sept 1, 2006, Dresden, Germany.
- R. Ranjan, A. Harwood, and R. Buyya, *SLA-Based Coordinated Superscheduling Scheme for Computational Grids*, Proceedings of the 8th IEEE International Conference on Cluster Computing (Cluster 2006, IEEE CS Press, Los Alamitos, CA, USA), Sept. 27-30, 2006, Barcelona, Spain.
- K. Kim and R. Buyya*, Policy-based Resource Allocation in Hierarchical Virtual Organizations for Global Grids*, Proceedings of the 18th International Symposium on Computer Architecture and High Performance Computing (IEEE CS Press, Los Alamitos, CA, USA), Oct. 17-20, 2006, Ouro Preto, Brazil.
- C. S. Yeo and R. Buyya, A Taxonomy of Market-based Resource Management Systems for Utility-driven Cluster Computing, *Software: Practice and Experience*, 36(13), 1381-1419pp, Wiley Press, New York, USA, Nov. 2006.
- C. S. Yeo and R. Buyya, *Integrated Risk Analysis for a Commercial Computing Service*, Proceedings of the 21st IEEE International Parallel and Distributed Processing Symposium (IEEE CS Press, Los Alamitos, CA, USA), March 26-30, 2007, Long Beach, California, USA.

Publications

- The Lab publication record since its inception in 2002 highlighted in the Table below:

Year / Publication Type	2002	2003	2004	2005	2006
Books/Proceedings Edited	1	1	1	1	5
Journal Papers	6	1	4	5	6
Book Chapters	1	0	0	4	4
Conference Papers	4	7	9	16	15
Magazine/Other Articles	0	0	1	2	4
Total	12	9	15	28	34

Book Chapters

1. Chee Shin Yeo, Rajkumar Buyya, Hossein Pourreza, Rasit Eskicioglu, Peter Graham, and Frank Sommers, Cluster Computing: High-Performance, High-Availability, and High-Throughput Processing on a Network of Computers, *Handbook of Nature-Inspired and Innovative Computing: Integrating Classical Models with Emerging Technologies*, Albert Zomaya (editor), pp.521-551 (Chapter 16), ISBN 0-387-40531-1, Springer Science+Business Media Inc., New York, USA, 2006.
2. Sushant Goel and Rajkumar Buyya, Data Replication Strategies in Wide Area Distributed Systems, *Enterprise Service Computing: From Concept to Deployment*, Robin G. Qiu (ed), pp. 211-241, ISBN 1-599044181-2, Idea Group Inc., Hershey, PA, USA, 2006.
3. Harold Soh, Shazia Haque, Weili Liao and Rajkumar Buyya, Grid Programming Models and Environments, *Advanced Parallel and Distributed Computing: Evaluation, Improvement and Practice*, Yuanshun Dai, Yi Pan, Rajive Raje (eds), pp. 141-173, ISBN: 1-60021-202-6, Nova Science Publishers, USA, 2006.
4. Manjuka Soysa, Rajkumar Buyya, and Baikunth Nath, GridEmail: Economically Regulated Internet-based Interpersonal Communications, *Advanced Parallel and Distributed Computing: Evaluation, Improvement and Practice*, Yuanshun Dai, Yi Pan, Rajive Raje (eds), pp. 279-295, ISBN: 1-60021-202-6, Nova Science Publishers, USA, 2006.

Proceedings Edited

1. Alberto Ferreira De Souza, Rajkumar Buyya, and Wagner Meira Jr. (editors), *Proceedings of the 18th Symposium on Computer Architecture and High Performance Computing (SBAC-PAD 2006, Ouro Preto, Brazil)*, IEEE Computer Society Press, Los Alamitos, California, USA.
2. Rajkumar Buyya and Tianchi Ma (editors), Proceedings of the 4th Australasian Symposium on Grid Computing and e-Research (*AusGrid 2006*, Hobart, Australia), Volume 54 - ACSW Frontiers 2006, ISBN 1-920-68236-8, Australian Computer Society, Sydney, Australia, Jan. 2006.
3. Nong Xiao, Rajkumar Buyya, and Yunhao Liu (editors), *Proceedings of the 5th International Conference on Cooperative and Grid Computing (GCC 2006, Changsha, China)*, ISBN 0-7695-2694-2, IEEE Computer Society Press, Los Alamitos, California, USA.
4. Nong Xiao, Rajkumar Buyya, Yunhao Liu, and Guangwen Yang (editors), *Proceedings of the 5th International Conference on Cooperative and Grid Computing Workshops (GCCW 2006, Changsha, China)*, ISBN 0-7695-2695-0, IEEE Computer Society Press, Los Alamitos, California, USA.

5. Dennis Gannon, Rosa Badia, and Rajkumar Buyya (editors), *Proceedings of the 7th IEEE/ACM International Conference on Grid Computing (Grid 2006, Barcelona, Spain)*, ISBN 1-4244-0344-8, IEEE Press, New York, USA.

Journal Papers

1. Srikumar Venugopal, Rajkumar Buyya, and Kotagiri Ramamohanarao, A Taxonomy of Data Grids for Distributed Data Sharing, Management and Processing, ACM Computing Surveys, Volume 38, No. 1, Pages:1-53, ISSN 0360-0300, ACM Press, New York, USA, March 2006.
2. Jia Yu, Srikumar Venugopal, and Rajkumar Buyya, A Market-Oriented Grid Directory Service for Publication and Discovery of Grid Service Providers and their Services, The Journal of Supercomputing, Volume 36, No. 1, Pages:17-31, ISSN: 0920-8542, Springer Science+Business Media, Berlin, Germany, April 2006.
3. Srikumar Venugopal, Rajkumar Buyya and Lyle Winton, A Grid Service Broker for Scheduling e-Science Applications on Global Data Grids, Concurrency and Computation: Practice and Experience, Volume 18, Issue 6, Pages: 685-699, Wiley Press, New York, USA, May 2006.
4. Chee Shin Yeo and Rajkumar Buyya, A Taxonomy of Market-based Resource Management Systems for Utility-driven Cluster Computing, Software: Practice and Experience (SPE), Volume 36, Issue 13, Pages: 1381-1419, Wiley Press, New York, USA, Nov. 2006.
5. Alan Yim and Rajkumar Buyya, Decentralized Media Streaming Infrastructure (DeMSI): An Adaptive and High-Performance Peer-to-Peer Content Delivery Network, Journal of Systems Architecture, Volume 52, Issue 12, Pages: 737-772, ISSN 1383-7621, Elsevier Science, The Netherlands, Dec. 2006.
6. Jia Yu and Rajkumar Buyya, Scheduling Scientific Workflow Applications with Deadline and Budget Constraints using Genetic Algorithms, Scientific Programming Journal, Volume 14, Issue 3-4, Pages: 217 - 230, ISSN: 1058-9244, IOS Press, Amsterdam, The Netherlands.

Magazine Papers

1. Krishna Nadiminti and Rajkumar Buyya, Enterprise Grid Computing: State-of-the-Art, Enterprise Open Source Journal, pages 19-22, Thomas Communications Inc, Dallas, Texas, USA, March/April 2006.
2. Krishna Nadiminti, Marcos Dias de Assunção, and Rajkumar Buyya, Distributed Systems and Recent Innovations: Challenges and Benefits, InfoNet Magazine, Volume 16, Issue 3, Victorian Information Technology Teachers Association (VITTA) Inc., Melbourne, Australia, Sept. 2006.
3. Rajkumar Buyya, Al-Mukaddim Khan Pathan, James Broberg, and Zahir Tari, A Case for Peering of Content Delivery Networks, IEEE Distributed Systems Online, Vol. 7, No. 10, IEEE CS Press, Los Alamitos, CA, USA, Oct. 2006.
4. Krishna Nadiminti and Rajkumar Buyya, Global Grid computing: Where are we today?, Enterprise Open Source Journal, Thomas Communications Inc, Dallas, Texas, USA, Nov/Dec. 2006.

Conference Papers

1. Marcos Dias de Assuncao and Rajkumar Buyya, An Evaluation of Communication Demand of Auction Protocols in Grid Environments, Proceedings of the 3rd International Workshop on Grid Economics & Business (GECON 2006), World Scientific Press, May 16, 2006, Singapore.

2. Kyong Hoon Kim, Rajkumar Buyya, and Jong Kim, Imprecise Computation Grid Application Model for Flexible Market-based Resource Allocation, Proceedings of the 6th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2006, IEEE CS Press, Los Alamitos, CA, USA), May 16-19, 2006, Singapore.
3. Jia Yu and Rajkumar Buyya, A Budget Constrained Scheduling of Workflow Applications on Utility Grids using Genetic Algorithms, Workshop on Workflows in Support of Large-Scale Science, Proceedings of the 15th IEEE International Symposium on High Performance Distributed Computing (HPDC 2006, IEEE CS Press, Los Alamitos, CA, USA), June 19-23, 2006, Paris, France.
4. Chee Shin Yeo and Rajkumar Buyya, Managing Risk of Inaccurate Runtime Estimates for Deadline Constrained Job Admission Control in Clusters, Proceedings of the 35th International Conference on Parallel Processing (ICPP 2006, IEEE CS Press, Los Alamitos, CA, USA), August 14-18, 2006, Columbus, Ohio, USA.
5. Martin Placek and Rajkumar Buyya, Storage Exchange: A Global Trading Platform for Storage Services, Proceedings of the 12th International European Parallel Computing Conference (EuroPar 2006, LNCS, Springer-Verlag, Berlin, Germany), Aug. 29-Sept 1, 2006, Dresden, Germany.
6. Srikumar Venugopal and Rajkumar Buyya, A Set Coverage-based Mapping Heuristic for Scheduling Distributed Data-Intensive Applications on Global Grids, Proceedings of the 7th IEEE/ACM International Conference on Grid Computing (Grid 2006, IEEE CS Press, Los Alamitos, CA, USA), Sept. 28-29, 2006, Barcelona, Spain.
7. Rajiv Ranjan, Aaron Harwood, and Rajkumar Buyya, SLA-Based Coordinated Superscheduling Scheme for Computational Grids, Proceedings of the 8th IEEE International Conference on Cluster Computing (Cluster 2006, IEEE CS Press, Los Alamitos, CA, USA), Sept. 27-30, 2006, Barcelona, Spain.
8. Hussein Gibbins and Rajkumar Buyya, Gridscape II: A Customisable and Pluggable Grid Monitoring Portal and its Integration with Google Maps, Proceedings of the 5th International Conference on Grid and Cooperative Computing (GCC 2006, IEEE CS Press, Los Alamitos, CA, USA), Oct. 21-23, 2006, Changsha, China.
9. Kyong Hoon Kim and Rajkumar Buyya, Policy-based Resource Allocation in Hierarchical Virtual Organizations for Global Grids, Proceedings of the 18th International Symposium on Computer Architecture and High Performance Computing (SBAC-PAD 2006, IEEE CS Press, Los Alamitos, CA, USA), Oct. 17-20, 2006, Ouro Preto, Brazil.
10. Xingchen Chu, Andrew Lonie, Peter Harris, S.Randall Thomas, and Rajkumar Buyya, KidneyGrid: A Grid Platform for Integration of Distributed Kidney Models and Resources, Proceedings of the 4th International Workshop on Middleware for Grid Computing (MGC 2006, ACM Press, New York, USA), Nov. 27, 2006, Melbourne, Australia.
11. Henry Lin, Jemal Abawajy, and Rajkumar Buyya, Economy-Based Data Replication Broker, Proceedings of the 2nd IEEE International Conference on E-Science and Grid Computing (E-Science 2006, IEEE CS Press, Los Alamitos, CA, USA), Dec. 4- 6, 2006, Amsterdam, Netherlands.
12. Xingchen Chu, Tom Kobialka, Bohdan Durnota, and Rajkumar Buyya, Open Sensor Web Architecture: Core Services, Proceedings of the 4th International Conference on Intelligent Sensing and Information Processing (ICISIP 2006, IEEE Press, Piscataway, New Jersey, USA, ISBN 1-4244-0611-0, 98-103pp), Dec. 15-18, 2006, Bangalore, India.
13. Carlos Queiroz, Marco A. S. Netto, Rajkumar Buyya, Message Passing over .NET-based Desktop Grids, Proceedings of the HiPC 2006 Workshop on Cutting Edge Computing, 13th IEEE International Conference on High Performance Computing, Dec. 18-21, 2006, Bangalore, India.
14. Anthony Sulistio, Wolfram Schiffmann, Rajkumar Buyya, Advanced Reservation-based Scheduling of Task Graphs on Clusters, Proceedings of the 13th Annual IEEE

International Conference on High Performance Computing (HiPC 2006, LNCS 4297, Springer Verlag, Berlin, Germany), Dec. 18-21, 2006, Bangalore, India.

15. Thamarai Selvi Somasundaram, R.A.Balachandar, Vijayakumar Kandasamy, Rajkumar Buyya, Rajagopalan Raman, N.Mohanram and S.Varun, Semantic-based Grid Resource Discovery and its Integration with the Grid Service Broker, Proceedings of the 14th International Conference on Advanced Computing and Communications (ADCOM 2006, IEEE Press, Piscataway, New Jersey, USA, ISBN: 1-4244-0715-X, 84-89pp), Dec. 20 - 23, 2006, NITK, Surathkal, Karnataka, India.

Invited Presentations and Outreach

Keynote Talks at International Conferences

1. Grid Computing and the Gridbus Middleware: Making the Global Cyberinfrastructure for e-Science and e-Business a Reality, Keynote Talk, 11th International CSI Computer Conference (CSICC 2006), Computer Society of Iran, Tehran, Iran, Jan. 24-26, 2006.
2. Grid Computing: Emerging Trends, International Conference on Computing and Informatics (ICOCI 2006), June 6-8, 2006, Kuala Lumpur, Malaysia.
3. Gridbus Middleware: Building Utility Grids for Powering e-Science Applications, National e-Science Congress, Santiago, Chile, Sept. 6-7, 2006.
4. The Gridbus Middleware for Utility-Oriented Grid Computing, 3rd International Conference on Mobile, Ubiquitous, and Pervasive Computing (ObCom 2006), Vellor, India, Dec. 17-19, 2006.
5. Autonomic Grids and the Gridbus Toolkit, 14th International Conference on Advanced Computing and Communications (ADCOM 2006), Dec. 20-23, 2006, Surathkal, India.

Seminars

1. Grid Computing and the Gridbus Middleware, International Institute of Information Technology (I2IT), Pune, India, March 13, 2006.
2. Grid Computing and the Gridbus Middleware, Centre for Development of Advanced Computing, Pune, India, March 14, 2006.
3. Grid Computing and the Gridbus Middleware, Yahoo Inc. (India R&D Centre), Bangalore, India, March 15, 2006.
4. Grid Computing and the Gridbus Middleware, University of Ballarat, Australia, May 31, 2006.
5. Grid Computing and the Gridbus Middleware, Multimedia University, Cyberjaya, Malaysia, June 8, 2006.
6. Introduction to Grid Computing: Trends, Challenges, Technologies, Applications, Osaka University, Japan, July 10, 2006.
7. The Gridbus Middleware: Creating and Managing Utility Grids for Powering e-Science and e-Business Applications, Osaka University, Japan, July 12, 2006.
8. The Gridbus Middleware, The Complutense University of Madrid (UCM), Madrid, Spain, Sept. 21, 2006.
9. The Gridbus Middleware, Universidad Carlos III de Madrid, Madrid, Spain, Sept. 22, 2006.
10. Recent Advances in Grid Computing and The Gridbus Middleware, National University of Defence Technology, Changsha, China, Oct. 22, 2006.
11. Grid Computing & the Gridbus Middleware: Creating and Managing Utility Grids for Powering e-Science and e-Business Applications, IBM India Research Lab, Delhi, India, Dec. 26, 2006.

Conference Tutorials

1. Gridbus Middleware: Enabling Market-based Grid Computing for e-Science and e-Business a Reality, 6th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2006), May 16-19, 2006, Singapore.
2. Grid Computing and the Gridbus Toolkit, Spanish National Conference on Computer Paralelism ("Jornadas de Paralelismo"), Sept. 18-20, 2006, University of Castilla-La Mancha, Albacete, Spain.
3. Grid Computing and the Gridbus Middleware, 8th IEEE International Conference on Cluster Computing, Sept. 25th-28th, 2006, Barcelona, Spain.
4. Grid Computing and the Gridbus Middleware, 4th International Conference on Intelligent Sensing and Information Processing, 15-18 December 2006, Bangalore, India.
5. Grid Computing, 14th International Conference on Advanced Computing and Communications (ADCOM 2006), Dec. 20-23, 2006, Surathkal, India.

1. Grid Service Broker (v.3.0) Software

The Gridbus Project at the University of Melbourne, Australia is pleased to release a new version of Grid Service Broker that works with WSRF-compliant Grid resources. With version 3.0, the broker can also be hosted as a remote web service, which is compliant with the WSRF standard. The broker primarily mediates user access to distributed "autonomous" grid resources by (a) discovering suitable data sources for a given analysis scenario, (b) suitable computational resources, (c) optimally mapping analysis jobs to resources, (d) deploying and monitoring job execution on selected resources, (e) accessing data from local or remote data source during job execution and (f) collating and presenting results.

The broker provides (a) a declarative and dynamic parametric programming model and (b) a rich set of Java APIs for creating grid applications. It also allows programmers to create a user-level scheduler and middleware plugins that can replace default Computational and Data Grid scheduling algorithms that support service price-based resource allocation.

What's New:

- WSRF Compliant multi-user multi-application Grid Brokering service (enables clients to use a 'remotely hosted' Grid brokering service)
- Broker calling hosted applications (simple web-services)
- Support for GGF - JSDL standard (for single, non-parametric jobs)
- Gridbus Broker Workbench GUI, for easier composition, initialisation, monitoring and management of grid applications
- New service oriented modular design to allow vast improvements in scalability, reliability and robust failure management
- Enhanced flexibility, usability and adaptability
- Improved stability for all middleware
- Improvements in data-aware scheduling

Base Technologies:

The Gridbus Broker v3.0 supports/uses the following middleware:

Globus 2.4.x, Globus 4.0
Alchemi 1.0
OpenPBS 2.3,
SGE,
NWS 2.8,
SRB(Storage Resource Broker) 3.x

The Gridbus Broker v3.0 can utilise a resource via SSH for submitting and executing grid jobs on: OpenPBS 2.3, SGE, Fork (on Unix-like OSes). In addition, the Broker can make calls to simple webservices, to leverage hosted applications.

Download information:

The broker source code, binaries, documentation and manual can be downloaded from **http://www.gridbus.org/broker/**

2. Alchemi 1.0: A .NET-based Enterprise Grid Framework

Alchemi (http://www.alchemi.net/) is an "open source" software framework that allows you to painlessly aggregate the computing power of networked machines into a virtual supercomputer (computational grid) and to develop applications to run on enterprise grids. It has been developed at the GRIDS Laboratory within the Department of Computer Science and Software Engineering at the University of Melbourne, as part of the Gridbus project (http://www.gridbus.org). The development of Alchemi is partially sponsored by the Australian Research Council (ARC) and Microsoft (via academic support program in Australia). Most importantly, it is also supported by many other volunteers and community of developers through SourceForge: http://sourceforge.net/projects/alchemi

Alchemi has been designed with the primary goal of being easy to use without sacrificing power and flexibility and enables what we call "plug-and-play" enterprise grid computing. The Alchemi release packaging includes:

- The runtime machinery (Windows executables) to construct enterprise grids.
- A .NET API and tools to develop .NET grid applications and grid-enable legacy applications.

The main features of Alchemi v.1.0 include:

- A central Manager which controls and orchestrates operations on an Alchemi grid.
- Executors that are installed on each grid node, and run the work units given by the manager
- Voluntary (cycle-stealing) / Dedicate mode of execution
- Role-based security
- Enables a LAN / WAN / Internet wide grid (Executors can be configured to work across NAT/Firewalls : voluntary execution mode)
- Threads-based grid application programming environment
- File-based job execution to grid-enable legacy batch-mode programs
- .NET based infrastructure providing a range of development options

Alchemi has been very popular and is used by people from all over the world since early 2003. Some examples include:

- CSIRO / eWater CRC, Australia (Alchemi-based natural resource modelling)
- Tier Technologies, USA (Large scale document processing on Alchemi)
- StochastiX GmBH, Germany (Managed XLL, Alchemi plug-in to distribute spreadsheet computations)
- FMI Biomedical research institute, Switzerland (Detection of transcription factor patterns of mammalian genes)
- Satyam, India (Security and life science applications)
- Correlation Systems, Israel (estimating the location of an HF radio transmitter)

We would like thank all the contributors some of whom are listed below:
- Akshay Luther (Founder developer)
- Rajkumar Buyya (Mentor)
- Krishna Nadiminti (Active developer)
- Tibor Biro (Developer)
- And many others part of source-forge user/developer community who have contributed their time and effort towards advancing Alchemi.

To download the Alchemi software, please visit the Gridbus Project web site or Alchemi express site at: http://www.alchemi.net

3. Gridscape II

Grid computing has emerged as an effective means of facilitating the sharing of distributed heterogeneous resources, enabling collaboration in large scale environments. However, the nature of Grid systems, coupled with the overabundance and fragmentation of information, makes it difficult to monitor resources, services, and computations in order to plan and make decisions.

The GRIDS Lab and the Gridbus Project at the University of Melbourne are pleased to release the Gridscape II software which manages the gathering of information from arbitrary, heterogeneous and distributed sources and presents them together seamlessly within a single interface. It also leverages the Google Maps API in order to provide a highly interactive user interface. Gridscape II is simple and easy to use, providing a solution to those users who don't wish to invest heavily in developing their own monitoring portal from scratch, and also for those users who want something that is easy to customise and extend for their specific needs.

Gridscape aims at providing a high-level, user-friendly and highly customisable portal interface in order to present the status of Grid resources. It interacts with existing technology so that no additional installation or configuration of Grid resources is required. Major improvements over the previous implementation of Gridscape are that it supports the integration of multiple arbitrary information sources through an extensible design; it provides a simple customisation mechanism to allow it to be enhanced to meet the specific needs of each individual Grid portal. Other improvements are integration with Google Maps, simplified portal administration and the use of portlet-based web components which means it can be plugged into other Grid portals to compliment them.

The key features of Gridscape II are the following:

- It manages diverse forms of resource information from various types of information sources;
- It provides a simple framework for introducing new information service types;
- It provides simple portal management and administration;
- It provides a clear and intuitive presentation of resource information in an interactive and dynamic portal via Google Maps;

It has a flexible design and implementation such that core components can be reused in building new components, presentation of information can be easily changed and a high level of portability and accessibility (from the web browser perspective) can be provided.

Gridscape II currently comes with implementations for MDS2 (Globus 2) and MDS4 (Globus 4) information service types.

The developers of Gridscape II are: Hussein Gibbins and Rajkumar Buyya from the Grid Computing and Distributed Systems (GRIDS) Laboratory at the University of Melbourne, Australia.

For further information or to download the "open source" Gridscape II software, please visit:

- Gridbus Project Web page: http://www.gridbus.org/
- Gridscape II webpage: http://www.gridbus.org/gridscape

4. GridSim Toolkit 4.0

The Gridbus Project and the GRIDS (Grid Computing and Distributed Systems) Lab at the University of Melbourne, Australia has released the next-version of Grid simulation software, the GridSim Toolkit 4.0.

The new version of GridSim includes:

- two major new features: auction model and data grid
- a new packet scheduler for the network package
- a network reader to read a network topology from a file and automatically creates and link routers
- updates some of the network classes to incorporate this new packet scheduler

All components developed as part of the GridSim Toolkit are released as "open source" under the GPL license to encourage innovation and pass full freedom to our users.

The early version of our GridSim toolkit has been used/dowloaded by several academic and commercial organizations around the world including: California Institute of Technology, Argonne National Labs, University of Illinois, Manchester University, CERN, Carleton University, University of Ljubljana, National University of Singapore, Universidad de Castilla-LaMancha (UCLM) Spain, Federal University of Ceara (UFC) Brazil, BrunelUniversity UK, Indian Institute of Technology, Tsinghua University, Sun Microsystems, IBM, Unisys, HP, British Telecom and EMC Corp.

The GridSim software has been used for modeling and simulating many interesting systems. For example, Unisys's usage in data center modelling and University of Ljubljana's extension of GridSim to support DataGrid. Our own usages include simulating economic Grid scheduler in a competitive economy model, economic based cluster scheduler and cooperative Grid federation.

The contributors to the GridSim software (early/new version) are:

- Anthony Sulistio, GridS Lab @ The University of Melbourne.
- Rajkumar Buyya, GRIDS Lab @ The University of Melbourne.
- Manzur Murshed, GSCIT @ Monash University.
- Chee Shin Yeo, GridS Lab @ The University of Melbourne.
- Gokul Poduval and Chen-Khong Tham, National University of Singapore.
- Uros Cibej and Borut Robic, The University of Ljubljana, Slovenia.
- Marcos Dias de Assuncao, GridS Lab @ The University of Melbourne.

To download the GridSim software, usage documents and examples, please visit the Gridbus Project Web site at http://www.gridbus.org/gridsim/

Community Services (of Dr. Buyya)

IEEE Computer Society

1. Chair, IEEE Technical Committee on Scalable Computing

Journal Editorials

1. Associate Editor*, Future Generation Computer Systems (FGCS)* -- The International Journal of Grid Computing: Theory, Methods and Applications, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands.
2. Editorial Board Member, *International Journal of Parallel, Emergent and Distributed Systems* (IJPEDS), ISSN: 1744-5760, Taylor & Francis Group, UK.
3. Editorial Board Member, *International Journal of Web Services Research*, ISSN: 1545-7362, Idea Group Publications, USA, 2003 onwards.
4. Editorial Board Member, *International Journal of Grid and Utility Computing*, ISSN: 1741-847X, Inderscience Publishers, Geneva, Switzerland, 2004 onwards.
5. Editorial Board Member, *Multiagent and Grid Systems: An International Journal*, ISSN: 1574-1702, IOS Press, Amsterdam, The Netherlands, 2005 onwards.

Conference Steering Committee

2. Chair, IEEE/ACM International Symposium on Cluster Computing and the Grid: CCGrid 2006, Singapore
3. Co-Chair, International Conference on e-Science and Grid Computing: e-Science 2006, The Netherlands
4. Member, IEEE/ACM Supercomputing Conference: SC 2006, USA
5. Member, IEEE International Conference on Cluster Computing: Cluster 2006, Spain
6. Member, International Symposium on Computer Architecture and High Performance Computing: SBAC-PAD, Brazil
7. Member, IEEE/ACM International Conference on Grid Computing: Grid 2006, Spain

Conference Chair

1. Honorary Chair, International Conference on Mobile, Ubiquituos and Pervasive Computing (ObCom 2006), Vellore, India, Dec. 2006.

Program Committee Chair

1. Co-Chair, 5th International Conference on Grid and Cooperative Computing (GCC 2006), Oct. 21-23, 2006, Changsha, China.
2. Co-Chair, 18th Symposium on Computer Architecture and High Performance Computing (SBAC-PAD 2006), October 18-20 2006, Ouro Preto, Brazil.

Misc. Services Chair

1. Co-Chair, 4th International Workshop on Middleware for Grid Computing (MGC 2006), In conjunction with ACM/IFIP/USENIX 7th International Middleware Conference 2006 Melbourne, Australia - November 27 – December 1, 2006.
2. Industry Track Chair, 7th ACM/USENIX International Middleware Conference, November 27 - December 1, 2006, Melbourne, Australia.

3. Publications Chair, 7th IEEE International Conference on Grid Computing (Grid 2006), 28-29 September, Barcelona, Spain.

Technical Program Committee Memberships

1. 2nd IEEE International Conference on E-Science and Grid Computing (E-Science 2006), Dec. 4-6, 2006, Amsterdam, Netherlands.
2. Australian Telecommunication Networks and Applications Conference (ATNAC 2006), Dec. 4-6, 2006, Melbourne, Australia.
3. The 2006 International Symposium on Parallel and Distributed Processing and Applications (ISPA 2006), December 1-4, 2006, Sorrento, Italy.
4. 19th IEEE/ACM Supercomputing (SC 2006): The International Conference for High Performance Computing and Communications, November 11-17, 2006, Tampa, Florida, USA.
5. 18th International Conference on Parallel and Distributed Computing and Systems (PDCS 2006), November 13-15, 2006, Dallas, Texas, USA.
6. IEEE-CS 2006 John Vincent Atanasoff International Symposium on Modern Computing (ISMC 2006), October 3-6, 2006, Sofia , Bulgaria.
7. 3rd IEEE International Conference on Services Computing (SCC 2006), Sept. 18-22, 2006, Chicago, USA.
8. International Conference on Self-Organization and Autonomic Systems in Computing and Communications (SOAS 2006), September 18-21, 2006, Erfurt, Germany.
9. 12th International Conference on Parallel and Distributed Systems (ICPADS 2006), July 12-15, 2006, Minneapolis, Minnesota, USA.
10. Workshop on Workflows in Support of Large-Scale Science, In conjunction with 15th IEEE International Symposium on High Performance Distributed Computing (HPDC 2006), June 20, Paris, France.
11. 6th International Conference on Computational Science (ICCS 2006), May 28-31, 2006, Reading, UK.
12. 15th International World Wide Web Conference (WWW 2006), May 22-26, 2006, Edinburgh, UK.
13. International Conference on Integrated Internet Ad hoc and Sensor Networks (InterSense 2006), May 29-31, 2006, Nice, France.
14. 1st International Conference on Grid and Pervasive Computing (GPC 2005), May 3-5, 2006, Taichung, Taiwan.
15. 20th IEEE International Parallel and Distributed Processing Symposium (IPDPS 2006), April 26-29, 2006, Rhodes Island, Greece.

Community Information Sources

- Maintained a Grid Computing Information Centre at: http://www.gridcomputing.com, whose newsletter mailing list has over 2000 members. This website is often ranked as #1 source for grid computing by Google search engine.
- Maintained a Cluster Computing Information Centre at: http://www.buyya.com/cluster

International Visiting Researchers

- Prof. Sushil K Prasad, Georgia State University, Atlanta, USA (July-Aug, 2006), Jointly funded by GRIDS Lab, NICTA, and ARC RN for Sensor Networks, July-Aug, 2006.
- Prof. T. S. Selvi, Anna University, Chennai, India, (May-June, 2006), Funded by GRIDS Lab, May/June 2006.
- Julio López Albin, PhD student, University of Santiago, Spain, July-Oct. 2006.
- Agustin C. Caminero Herraez, PhD Student, Universidad de Castilla-La Mancha, Spain, Oct-Dec.2006.
- Roberto Podesta, PhD Student, Universita degli Studi di Genova, Italy, Oct-Dec.2006.
- Prof. Manish Parashar, Rutgers: The State University of New Jersey, Piscataway, USA, Nov. 2006.
- Dr. Yoshitake Kobayashi, The University of Electro-Communications, Tokyo, Japan, May-Dec. 2006.
- Prof. Dr. Christoph Reich, Hochschule Furtwangen University, Germany, Oct 2006-March 2007.
- Christian Vecchiola, PhD Student, Università degli Studi di Genova, Italy, Oct 2006-Jan.2007.
- Dr Kris Bubendorfer, Victoria University of Wellington, New Zealand, November 2006-July 2007.

Visiting Researcher Report: Prof. Sushil Prasad

Professor Sushil K. Prasad of Georgia State University, Atlanta, USA, was funded for a two-month research visit to University of Melbourne, Australia, during summer 2006 to collaborate with Prof. Buyya on Grid and Mobile Computing research, with Prof. Palaniswami on Sensor Networks, and with NICTA. The outcomes of the visit are as follows:

1. Prof. Prasad gave a series of talks to the Grid Computing group at Univ. of Melbourne on Parallel Algorithms and Data Structures, and on Middlewares. The final talk was on an open NICTA/UMLB colloquium entitled "SyD: A Middleware for Collaborative Applications over Small Heterogeneous Devices and for Distributed Biological Workflows over Web Services."

2. A joint proposal to National Science foundation was submitted entitled "PIRE: US - Australia - Canada Partnership in Developing Middleware Technologies for Enabling Mobile Grid" with Prof. Buyya and Prof. Palani. This also resulted in international collaborations with sensornet group at Oak Ridge National Lab and Acenet group at University of New Brunswick, Canada.

There are good reasons for integrating the handheld devices, such as cell phones and personal digital assistants (PDAs), and the myriad of sensor networks into the current computational and data grid infrastructure: (i) these devices are increasingly getting more capable in processing power, memory, and battery life, (ii) are getting better connected, and (iii) are proliferating. Harnessing their capabilities holds the key to a range of applications from homeland security to e-science. Prof. Prasad has designed and implemented a middleware for handheld and other devices to enable seamless embedded software development and their deployment on a heterogeneous set of devices across multiple networking protocols and data formats. They have also developed and prototyped a preliminary system which allows users to develop and execute simple workflows over actual web services deployed over the Internet, while the workflow is launched and monitored through a mobile PDA.

Prof. Buyya and Palani have developed robust middlewares for distributed computation and workflows over the grid infrastructure, and are developing a middleware for interfacing with sensor networks. This PIRE project proposed to leverage of these complementary works, and research into developing a mobile grid infrastructure which seamlessly allows (i) employing mobile devices as a window to the global grid, and (ii) extending the global grid to the mobile devices, wherein these devices act as servers for data (stored and sensed) and synergistically collaborate among themselves and with core grid for greatly enhanced utility.

3. Prof. Prasad co-advised a Ph.D. student of Prof. Buyya's lab, Anthony Solisto, on advance grid scheduling techniques, resulting in a joint paper entitled "GarQ: An Efficient Data Structure for Advance Reservations in Grid Computing". A follow up journal submission is planned.

In Grid systems, users may require assurance for completing their jobs on shared resources. Such guarantees can only be provided by reserving resources in advance. However, if many reservation requests arrive at a resource simultaneously, the overhead of providing such service will be significant. An efficient data structure for managing these reservations plays an important role in order to minimize the time complexity for searching available resources, adding new requests, and deleting existing reservations. Several data structures have

already been proposed for related scheduling problems, e.g. for admission control in network bandwidth reservation, including Linked Lists and Segment Tree.

In this paper, they first describe suitably modified versions of the Linked List and Segment Tree data structures in capable of dealing with advance reservations in computational Grids. For Segment Tree, this entailed developing a new algorithm for finding a free interval closest to the requested reservation. Next, it describes how these operations can be performed on Calendar Queue, a data structure commonly employed for discrete event simulations. It then proposes a Grid advanced reservation Queue (GarQ), which is a new data structure based on Calendar Queue and Segment Tree that improves some weaknesses of the aforementioned data structures. We demonstrate the superiority of the proposed structure by conducting a detailed performance evaluation on real workload traces.

Another joint Chapter/Journal paper between Prof. Prasad, Buyya, and Krishna Nandiminti has been planned on "Mobile grid middleware"

4. A project has been started to create a light-weight implementation of gridbus broker to enable it to interface with web services. The students involved are Chad Christopher and Yan Chen from Prasad Lab and Krishna Nandiminti and Srikumar from Prof.Buyya's lab. The main idea was to create a stack of lightweight componentswhere the scheduler was to be replaced by a 'matcher' and calls to the execution framework removed. The entire architecture has been laid out.

5. Some joint initial exploration has been carried out in utilizing SVM techniques developed by Prof. Palani's lab into formulating distributed algorithms for extending lifetime of sensor networks. Also, fleet application of SyD middleware is planned to be leveraged for Prof. Palani's mobile inventory and logistics framework.

Visiting Research Student Self Profile: Christian Vecchiola

I am a PhD Doctor in Computer Science graduated at the University of Genoa, Italy. I have been advised by Prof. Antonio Boccalatte and Prof. Massimo Paolucci. I am interested in the design and the development of evolvable software systems with a particular focus on agent based technology. I am one of the main software engineers and developers of the *AgentService* [1] project. *AgentService* is a framework for developing and deploying distributed multi-agent systems and has been the result of my PhD. studies. My interests in Computer Science span from Software Engineering, web-based and distributed systems, and compiler technology.

I have joined the GRIDS Lab as a research visitor and during my visit I have investigated the feasibility of using agent-based technologies as a support infrastructure for grid computing systems. In particular, I have investigated the use of the agent oriented approach to create a more flexible and evolvable infrastructure and I have worked on the integration between *Alchemi* and *AgenService*. In order to study and understand the architecture of *Alchemi* I developed *ImageGrid* a demo application using the Grid Computing Infrastructure provided by *Alchemi* to perform image filtering. The final result of my activity at the GRIDS Lab has been a prototype integrating instances of the *AgentService* agent platforms into an *Alchemi* based grid.

During 2006 I worked on extending the *AgentService* framework and enhancing it with high-level services such as native support for ontology management and interaction protocols. In 2006 I also worked on providing the *AgentService* framework with a reliable support for agent-based distributed computing. The framework has been enriched with services for easily discovering and publishing agent capabilities in a network of federated agent platforms and facilities for agent interaction. The strength of the designed infrastructure is based on a completely transparent support for remote agent interaction with no additional burden if compared to local interaction. More advanced services rely on the ability to support agent mobility. We implemented a software infrastructure allowing an agent to stop its activity and resume it into a remote execution context. The implementation of a mobile agent infrastructure has been the starting point for devising a prototype for the integration between *AgentService* and *Alchemi*. More details about the activity carried out during 2006 can be found in the following publications:

C. Vecchiola, A. Grosso, A. Boccalatte, *AgentService: a framework to develop distributed multi-agent systems*, accepted for publication to IJAOSE – International Journal of Agent Oriented Software Engineering 2007 Issue.

A. Grosso, R. Podestà, C. Vecchiola, A. Boccalatte, *Design and Implementation of a Grid Architecture over an Agent-Based Framework*, 4th International Conference in Central Europe on .NET Technologies, Plzen, 2006.

A. Boccalatte, A. Grosso, C. Vecchiola, *Implementing a Mobile Agent Infrastructure on the .NET Framework*, 4th International Conference in Central Europe on .NET Technologies, Plzen, 2006.

C. Vecchiola, A. Grosso, A. Boccalatte, *Integrating Ontology Support within AgentService*, WOA 2006, Dagli oggetti agli agenti – Sistemi Grid, P2P e Self, Catania, September 2006.

I am currently working with my research group on the *AgentService* framework and I am a co-organizer of the 2007 edition of the WOA workshop which is one of the most important events in Italy for researchers in the area of Agent Oriented Software Engineering (AOSE).

[1] http://www.agentservice.it

Member Self Profile: Srikumar Venugopal

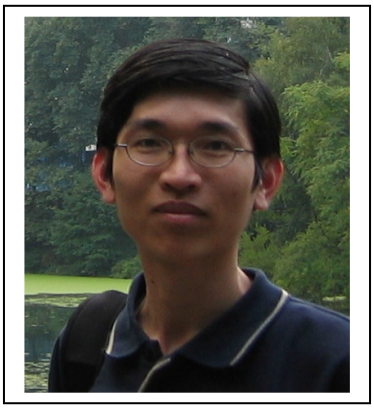
I have been a part of the Grid Computing and Distributed Systems Laboratory (GRIDS Lab) since its inception in 2002. I joined the University of Melbourne as a Ph.D. student under Dr. Rajkumar Buyya in the same year. The topic of my Ph.D. research was to investigate scheduling algorithms for distributed data-intensive applications on Grid resources distributed globally. In the course of my Ph.D. candidature, I developed the Gridbus Grid resource broker, initially to execute a high-energy physics application on the Grid to serve the needs of experimental particle physicists at the School of Physics in the University. The broker was then extended to be adopted by other communities with similar requirements.

The highlight of 2006, personally, was the successful completion of my Ph.D. candidature. In July 2006, I submitted my thesis for examination by external reviewers. The thesis was well received and passed without amendments by both the reviewers. Therefore, I was able to graduate as a Ph.D. scholar in Dec. 2006. I also had 2 journal papers published, one in the highly regarded *ACM Computing Surveys*, and the other in *Concurrency and Computation: Practice and Experience*. I have also had a paper accepted for presentation at the *International Conference of Grid Computing (Grid 2006)* held in Barcelona, Spain. I led a team that participated in the Melbourne University Entrepreneurs Challenge (MUEC) conducted by the MBA School, to gain experience for identifying commercial opportunities in my research. Unfortunately, we were unable to clear the first round but the experience gained will come in handy for future attempts.

After thesis submission, I joined the GRIDS Lab as a Research Fellow to pursue the new research themes that were identified in my Ph.D. work. I chose the GRIDS Lab over other opportunities because of the experience of the team members in similar research areas, and for the flexibility provided to pursue an independent but related research agenda. In 2007, I am working on the ARC-funded project on “QoS-based Scheduling of e-Research Workflows on Grids”. This project examines the execution of scientific workflows in a manner that satisfies users’ Quality of Service (QoS) metrics by identifying their requirements, discovering resources that can guarantee QoS by forming binding Service Level Agreements (SLAs), and then scheduling the workflow tasks in order to meet the requirements.

Therefore, the two main themes of my current research are to explore QoS-based workflow scheduling strategies, and the creation and negotiation of SLAs with Grid resources or resource providers. In particular, as many of the scientific workflows deal with large-sized datasets, the lessons learnt from my Ph.D. study will be applied while researching scheduling strategies. Some of the other issues that will be explored are the co-allocation of computational and data transfer components of a task, ensuring the required level of resource availability through advance reservations, and re-use of intermediate products of computation. The creation of SLAs with Grid resource providers requires that both parties come to a mutual agreement on the provisioning of resources, the monitoring of such provisions, and the penalties or rewards that apply when the SLA terms are violated or met. My work will focus on establishing protocols and strategies for negotiating SLAs so that neither of the parties is disadvantaged by entering into the SLA.

Member Self Profile: Chee Shin Yeo



I am a Ph.D. candidate in the GRIDS Laboratory. My general topics of interests include distributed computing (cluster, Grid and peer-to-peer computing), services computing and utility computing. My Ph.D. research focuses on Service Level Agreement (SLA) based resource allocation in clusters. A SLA acts as a contract agreed upon between a service provider and a service user that formally specifies the service quality the provider is required to provide. In particular, SLAs is vital in the utility computing model which allows users to easily switch to any commercial computing services to complete jobs whenever their needs arise, and simply pay only on usage without having to invest on resource infrastructure.

My previous work in the GRIDS Laboratory prior to my Ph.D. candidature includes developing a visual modeler for the GridSim Toolkit and constructing a taxonomy of computer-based simulations and its mapping to parallel and distributed systems simulation tools. My initial Ph.D. work proposes a pricing mechanism for utility-driven resource management and allocation in clusters. Next, I consider the penalty involved for violating SLAs when accepting more jobs with soft deadline requirement (SLA parameter) in order to enhance overall utility.

In 2006, I examine the impact of inaccurate runtime estimates on deadline constrained job admission control in clusters and how to reduce this impact by considering the risk of deadline delay[2]. This is important since job admission controls need accurate runtime estimates to effectively ensure service requirements can be fulfilled, whereas real workload traces show that runtime estimates provided by users are often inaccurate and overestimated.

I also develop a taxonomy that classifies how market-based RMSs can support utility-driven cluster computing in practice. The taxonomy which focuses on five perspectives (market model, resource model, job model, resource allocation model, and evaluation model) is then used to survey current research developments and identify outstanding issues[3].

Finally, I contribute to a book chapter on cluster computing that provides the reader with background knowledge of clusters, including interconnect technologies and communication software, Single System Image (SSI), Resource Management System (RMS) middleware, programming models, and user applications[4].

---

[2] Chee Shin Yeo and Rajkumar Buyya, Managing Risk of Inaccurate Runtime Estimates for Deadline Constrained Job Admission Control in Clusters, Proceedings of the 35th International Conference on Parallel Processing (ICPP 2006, IEEE CS Press, Los Alamitos, CA, USA), August 14-18, 2006, Columbus, Ohio, USA.

[3] Chee Shin Yeo and Rajkumar Buyya, A Taxonomy of Market-based Resource Management Systems for Utility-driven Cluster Computing, Software: Practice and Experience (SPE), Volume 36, Issue 13, Pages: 1381-1419, Wiley Press, New York, USA, Nov. 2006.

[4] Chee Shin Yeo, Rajkumar Buyya, Hossein Pourreza, Rasit Eskicioglu, Peter Graham, and Frank Sommers, Cluster Computing: High-Performance, High-Availability, and High-Throughput Processing on a Network of Computers, Handbook of Nature-Inspired and Innovative Computing: Integrating Classical Models with Emerging Technologies, Albert Zomaya (editor), pp.521-551 (Chapter 16), ISBN 0-387-40532-1, Springer Science+Business Media Inc., New York, USA, 2006.

Member Self Profile: Marcos Dias de Assunção

PHONE: 03 83441346

My name is Marcos Dias de Assunção. I was born in a small town called Videira located in the state of Santa Catarina in the south of Brazil. I have grown up and spent the most of my life in another small town called Fraiburgo, also situated in Santa Catarina. I have achieved a Masters in Computer Science at the Federal University of Santa Catarina in Florianópolis, Brazil.

I joined GRIDS Lab in March 2005 when I started my PhD in computer science at the University of Melbourne. Since then, I have been working on the design of architectures, mechanisms and related policies for collaborative inter-Grid resource allocation enabled by peering arrangements amongst Grids. We term "Grid Internetworking" the mechanisms for resource provisioning, selection and allocation across Grids. GRIDS Lab is undoubtedly a great environment to carry out such a work, as it has several members with solid knowledge on the distributed computing area.

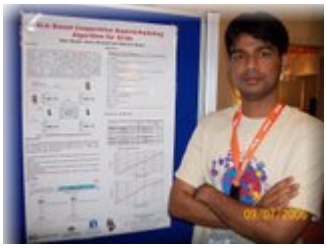
In 2006, we finalised a report that shows how network-based systems, such as the Internet, grow enabled by a mechanism that allows for the formation of networks of networks. Our work is motivated by the lack of such mechanisms in Grid computing. In that report, we compare Grid with the Internet, advocate that it is necessary to enable peering between Grids, identify key limitations in Grid technology and propose an architecture for internetworking of Grids. We have submitted this report to the journal "Concurrency and Computation: Practice and Experience".

One of the key challenges of Grid internetworking is to enable inter-Grid resource allocation. In this regard, we have been focusing on investigating mechanisms and policies for inter-Grid resource allocation. We initially considered the use of auctions for the inter-Grid resource allocation. As we envisioned a large-scale scenario, we considered that it would be important to investigate the communication demands of different kinds of auction protocols. An outcome of these experiments has been published in the proceedings of the 3rd Workshop on Business Models for Grid Computing.

We have collaborated with the University of Bayreuth in designing and implementing a framework that is suitable for us to model and simulate the mechanisms and policies for inter-Grid resource allocation. Such framework also allows the modelling and evaluation of various provisioning policies for utility data centres and service oriented computing. This work has been published as a technical report of GRIDS Lab. The University of Bayreuth is currently using this framework to model and simulate a self-organising economic model for Grid resource allocation.

We are currently investigating mechanisms that allow Grids to use one another's spare resources when their user communities require additional resources. We term "peering policies" the mechanisms and policies that enable the resource allocation across Grids for these scenarios. We are investigating ways by which Grids can exchange resources to enable the deployment of adaptive applications that can span multiple Grids and grow and shrink in terms of resource consumption. We plan to have solid empirical and theoretical results on this topic during 2007.

Member Self Profile: Rajiv Ranjan



I am a final year PhD student in the GRIDS Laboratory and Peer-to-Peer Networks Group. My thesis co-advisors are Dr. Rajkumar Buyya and Dr. Aaron Harwood. I am broadly interested in the design of both experimental and theoretical aspects of decentralised network-based systems in particular Grid computing systems. The primary focus of my Phd research is to develop fundamental algorithms and mechanism design policies to facilitate a large scale, decentralised and federated Grid resource sharing environment.

During first part of 2006, we investigated a decentralised mechanism design policy with focus on broker-to-broker coordination protocol. Specifically, we developed a Service Level Agreement (SLA) based Grid superscheduling methodology to facilitate a cooperative resource leasing environment. We based our SLA[5] negotiation model on the well known agent coordination mechanism known as Contract Net Protocol. Our approach allows resource owners to have finer control over the resource allocation which is something that is not possible with traditional mechanisms. It inhibits Grid schedulers such as Resource brokers from submitting unbounded amounts of work to the resources. Once, SLA is finalised the Grid users are assured that the desired Quality of Service (QoS) shall be delivered by the system.

Following our SLA work, we shifted efforts towards developing efficient decentralised resource discovery algorithms for Grid computing systems. Resource discovery activity involves searching for the appropriate resource types that match the user's application requirements. To this end, we developed a comprehensive taxonomy and survey paper on Peer-to-Peer (P2P) discovery of Grid resource information[6]. The article presents a state of art in P2P based indexing of *d*-dimensional Grid resource data. We also present a P2P taxonomy that classifies current resource discovery approaches based on three dimensions including P2P network organisation, *d*-dimensional data organisation and *d*-dimensional query routing.

We also proposed a novel solution to decentralised resource indexing[7] in a federated resource sharing environment. We utilised a spatial publish/subscribe index for organising distributed grid resource data. Distributed Hash Table (DHT) routing substrate forms the basis for delegation of *d*-dimensional service messages. DHTs are proven to be self-organising, fault-tolerant and scalable. Further, publish/subscribe way of resource discovery adheres well to the need of Grid computing participants who are separated in time and space. We validated our resource discovery algorithm through extensive simulation based study.

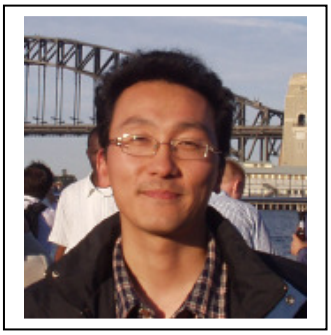
---

[5] Rajiv Ranjan, Aaron Harwood, and Rajkumar Buyya, A SLA-Based Coordinated Superscheduling Scheme and Performance for Computational Grids , In Proceedings of the 8th IEEE International Conference on Cluster Computing (Cluster 2006), 8 pages, IEEE Computer Society Press, September 27 - 30, 2006, Barcelona, Spain.

[6] Rajiv Ranjan, Aaron Harwood, and Rajkumar Buyya, A Study on Peer-to-Peer Based discovery of Grid Resource Information (revision submitted to the IEEE Communication Surveys and Tutorials).

[7] Rajiv Ranjan, Lipo Chan, Aaron Harwood, Rajkumar Buyya, and Shanika Karunasekera. A Scalable, Robust, and Decentralized Resource Discovery Service for Large Scale Federated Grids, (Submitted to IEEE Grid2007).

Member Self Profile: Kyong Hoon Kim



I have been a visiting research staff as a post-doctorial position since October in 2005. I received my Ph.D degree in Computer Science and Engineering at POSTECH (Pohang University of Science and Engineering), Korea in 2005. My research fellowship is partially from the Information and Telecommunication National Scholarship program for post-doctoral research fellows funded by the Ministry of Information and Communication (MIC) of Korea.

My main research topic in GRIDS lab includes:
(1) Resource allocation in Virtual Organizations (VOs) for Global Grids: In global Grid computing, users and resource providers share resources and services through VOs. In VO-based Grid environments, users and resource providers agree upon Service Level Agreements (SLAs) with their VOs, such as the amount of resource sharing. The VO-wide resource allocation problem becomes an emerging research topic, which enables users to access resources based on the SLAs.
(2) Power-aware scheduling of cluster systems: Traditional research interest in cluster systems has been high performance, such as high throughput, load balancing, and so on. However, recent research has focused on reducing power consumption in cluster systems. There are two main reasons for need of power aware computing in cluster systems: operational cost and system reliability. One dominating factor in the operational cost of data centers comes from electricity cost. In addition, larger power consumption causes increased temperature, which decreases the system reliability. Thus, power-aware scheduling provides an energy-efficient scheme to schedule jobs in clusters without much degradation of performance.
(3) Real-time scheduling: The real-time scheduling problem deals with scheduling tasks to meet their deadlines. Since it is a traditional problem, it has a lot of applications in Grid computing. For example, distributed multimedia applications or stream-based applications require the deadline constraint as well as much computing.

My work in 2006 focused on VO-based scheduling, cluster scheduling, and real-time systems. I also collaborated with other members for Grids. The followings are my publications in 2006.

(1) Kyong Hoon Kim and Rajkumar Buyya, "Policy-based Resource Allocation in Hierarchical Virtual Organizations for Global Grids," Proc. of the 18th International Symposium on Computer Architecture and High Performance Computing (SBAC-PAD 2006, IEEE CS Press, Los Alamitos, CA, USA), Ouro Preto, Brazil, October 2006.

(2) Kyong Hoon Kim, Rajkumar Buyya, and Jong Kim, "Imprecise Computation Grid Application Model for Flexible Market-based Resource Allocation," Proc. of the 6th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2006), Singapore, May 2006.

(3) Kyong Hoon Kim and Jong Kim, "An Energy-Efficient FEC Scheme for Weakly Hard Real-Time Communications in Wireless Networks," Proc. of 12th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Sydney, Australia, August 2006.

(4) Kyong Hoon Kim, Jong Kim, and Sung Je Hong, "Dual-mode r-reliable Task Model for Flexible Scheduling in Reliable Real-time Systems," Proc. of the 2006 IFIP International Conference on Embedded and Ubiquitous Computing (EUC '06), LNCS 4096, pp. 308-317, Seoul, Korea, August 2006.

Member Self Profile: Xingchen Chu

My name is Xingchen Chu. I am 26 and come from Changsha , Hunan Province, China. I joined the GRIDs lab in early Feburary 2006 as a Research Developer right after I got my Master of Information Technology degree in the University of Melbourne. I have been in Australia over 3 years and am quite happy to live in such a beautiful country and work with a group of great and ensuiatism people. I have learned a lot of new things from everyone in the GRIDs lab and I believe it is a great opptunity for me to improve my skills regarding to both technology and personality point of view. Apart from working, I also like to travel with my friends and colleagues around the country. Moreover, I love sports especially basketball and soccer. I always play with my friends as a team in my spare time. Of course, reading is aonther thing I really love to do after working, I have done intensive readings about the new technology treads in computing area to catch up and refresh my minds. Since recently, I begin to learn Economics and Finance as part time in the University. I have gained a lot of interests in economics and probably started to think as an economists. I think it will benefit both my future and my current research activity in this Lab.

Since I have joined the GRIDS lab, my main responsibility is to design and develop software systems that demonstrate concepts in the area of Grids and distributed systems research. Below is the list of activities I have done:

- Led the design and development of the first prototype of SensorWeb middleware which is part of the NICTA Open Sensor Web Architecture project and provides a high level service-oriented abstraction by mediating access to heterogeneous sensors. (Java, Web Services, TinyOS, NesC)
- Led the re-design and development of v.3.0 of the Gridbus Service Broker which allows Grid resource virtualization by mediating access to shared, heterogeneous global Grid resources. The Gridbus Broker is built on a layered service-oriented architecture and object-oriented design, and employs advanced economy and data-grid scheduling algorithms to meet users' QoS requirements (Java, Hibernate, Globus, WSRF)
- Developed the Gridbus Broker workbench which is a GUI for preparation, execution and monitor the Grid applications over the broker. (Java Swing, Gridbus Broker)
- Developed a portal that can prepare, execute, monitor and visualize simulations of distributed kidney models. The portal is built on top of Gridsphere framework utilizing JSF, WSRF and Gridbus Broker technologies. (Gridsphere, Java Portlet, JSF, WSRF, Gridbus Broker)
- Developed a knowledge-based interpretation and representation system (web and windows version) for human respiratory system. (Gridsphere, Java Portlet, Grdibus Broker, Java Swing)
- Maintained and enhanced the .NET based enterprise Grid system: Alchemi. (Visual Studio .NET, C#)

I also acted as a teaching assistant for Distributed System and Grid computing subject which is a part of the Masters degrees in Distributed Computing, IT, and Software Systems Engineering course at the CSSE Dept.

Member Self Profile: Chao Jin

I am Chao Jin from Beijing, China. My research interests focus on storage system and distributed system, including Grid and P2P system.

I joined GRIDS Lab at May 2006. Since then, I mainly have been working on .NET-based Grid computing platform for data-intensive applications, which aims to support a convenient programming model and automatic deployment in the environment with large scale distributed computing resources.

GRIDS lab is a fantastic research group, where there are lots of creative students and colleagues, including our knowledgeable mentor, Dr. Rajkumma Buyya. Furthermore, the famous work of GRIDS lab attracts lots of researchers across the world to visit us. During the first half year, I learned lots of interesting problems through the discussion with researchers from America, Korea, Japan, Germany, Singapore, New Zealand and Netherlands, etc. Our internal seminar with Europe Grid researchers also benefited me a lot.

In 2006, my main work is to build a dataflow system over .NET platform, which supports a dataflow programming model and a dataflow engine, for coarse-grained distributed data intensive applications. The dataflow programming model provides users with a transparent interface for application programming and execution management in a parallel and distributed computing environment. The dataflow engine dispatches the tasks onto candidate distributed computing resources in the system, and manages failures and load balancing problems in a transparent manner. Currently our system can support complex applications, such as FFT (Fast Fourier Traslation) and matrix computation etc. This system has been deployed in .NET lab in the University of Melbourne and provides free computation power through cycle-stealing to researchers.

Within this system, I employed a just-in-time scheduling policy to handle the dynamic features in desktop grid environments. To avoid the bottleneck problem from single manager server, a P2P manner is adopted in the data traffic between nodes involved in the dataflow execution. Furthermore a replication based method is used to improve the reliability of the computing service.

I have summarised some of my results in a Technical Report and a GridAsia conference paper. I embedded the main features of the dataflow system with Aneka, which is a third generation desktop grid system and aims to support pluggable scheduling and execution service for different requirements over Grid environments. I involved the design, implementation and testing of Aneka system.

In 2007, I plan to extend my work and focus on scheduling algorithm, resource allocation mechanism and service oriented computing platform. Furthermore, since currently multi-core CPU presents great challenges for our computer researchers, I also have great interests to work on efficient programming model to improve the software productivity over multi-core platform.

Member Self Profile: Jia Yu

I am a PhD student in the GRIDS Laboratory. My thesis advisors are Dr. Rajkumar Buyya and Dr. Rao Kotagiri. The major focus of my PhD research is workflow management and scheduling algorithms for Grid computing.

During 2006, we have investigated a number of workflow scheduling algorithms such as min-min, sufferage and GRASP which have been applied in Grid environments. Specifically, we have examined problems of scheduling workflows on utility Grids and developed budget and deadline constrained workflow scheduling using genetic algorithms[8, 9].

We have also applied Multi-Objective Evolutionary Algorithms (MOEAs) for the workflow execution planning problem. Our goal was to simultaneously minimize two conflicting objectives-execution time and execution price while meeting users' maximum time constraint (deadline) and price constraint (budget). Corresponding fitness functions, which incorporate minimization objectives and penalty functions for the constraints, have been developed[10].

[8] Jia Yu and Rajkumar Buyya, A Budget Constrained Scheduling of Workflow Applications on Utility Grids using Genetic Algorithms, Workshop on Workflows in Support of Large-Scale Science, Proceedings of the 15th IEEE International Symposium on High Performance Distributed Computing (HPDC 2006, IEEE CS Press, Los Alamitos, CA, USA), June 19-23, 2006, Paris, France.

[9] Jia Yu and Rajkumar Buyya, Scheduling Scientific Workflow Applications with Deadline and Budget Constraints using Genetic Algorithms, Scientific Programming Journal, Volume 14, Issue 3-4, Pages: 217 - 230, ISSN: 1058-9244, IOS Press, Amsterdam, The Netherlands.

[10] Jia Yu, Michael Kirley, Rajkumar Buyya, Multi-objective Planning for Workflow Execution on Grids, Grid 2007, submitted.

Member Self Profile: Anthony Sulistio

I am a Ph.D. candidate in the GRIDS Laboratory. My general topics of interests include distributed computing (cluster, Grid and peer-to-peer computing), advance reservation, simulation and software engineering. My Ph.D. research focuses on Modelling and simulation of reservation and economy-based management and scheduling in Global Grids. Advanced Reservation (AR) is a process of requesting resources for use at a specific time in the future. Common resources that can be reserved or requested are processors, memory, disk space and network bandwidth. AR in a scheduling system solves the above problem by allowing users to gain simultaneous and concurrent access to adequate resources for applications to be executed in parallel. AR also guarantees the availability of resources to users and applications at the specified times in the future.

My previous work in the GRIDS Laboratory prior to my Ph.D. candidature includes developing a visual modeler for the GridSim Toolkit and constructing a taxonomy of computer-based simulations and its mapping to parallel and distributed systems simulation tools. My initial Ph.D. work extends the GridSim Toolkit to support AR capabilities[11]. In addition, I incorporate network Quality of Service (QoS) and Data Grids functionalities into the GridSim Toolkit.

In 2006, I examined on how to schedule task graphs on a cluster system using AR[12]. Moreover, to improve resource utilization, I proposed a scheduling solution (AR scheduler) by interweaving one or more task graphs within the same reservation block and/or backfilling with other independent jobs. The results showed that the AR scheduler performs better than the First Come First Serve (FCFS) and Easy backfilling algorithms for reducing both the reservation duration time and the total completion time.

I also developed a new data structure, a Grid advanced reservation Queue (GarQ), to efficiently search for available CPUs, to add new requests, and to delete existing reservations[13]. GarQ is an array-based data structure inspired by Calendar Queue and Segment Tree. According to the performance evaluation, whose input is taken from real workload traces such as DAS2 fs0 from Vrije University in Amsterdam, GarQ manages to perform much better on average than Segment Tree, Linked List and Calendar Queue for the above reservation operations.

[11] Anthony Sulistio and Rajkumar Buyya, A Grid Simulation Infrastructure Supporting Advance Reservation, Proceedings of the 16th International Conference on Parallel and Distributed Computing and Systems (PDCS), pp. 1-7, November 9-11, 2004, Cambridge, Boston, USA..

[12] Anthony Sulistio, Wolfram Schiffmann, and Rajkumar Buyya, Advanced Reservation-based Scheduling of Task Graphs on Clusters, Proceedings of the 13th Annual IEEE International Conference on High Performance Computing (HiPC), Dec. 18-21, 2006, Bangalore, India.

[13] Anthony Sulistio, Uros Cibej, Sushil Prasad, Borut Robic and Rajkumar Buyya GarQ: An Efficient Data Structure for Advanced Reservations in Grid Computing, Technical Report, Grid Computing and Distributed Systems Laboratory, University of Melbourne, Australia, 2007.

Member Self Profile: Marco A. S. Neeto

Phone: 0432185160

I am Marco A. S. Netto, I have a Bachelor (2002) and Master degree (2004) in Computer Science, both from the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Brazil. Currently I am a second year PhD student at the University of Melbourne, Australia. My main interests are scheduling of parallel and distributed applications and resource management of computational systems.

In 2000, when I was still an undergraduate, I started to get interest on research management and scheduling. In that year I joined a new research centre on high performance computing (CPAD), which is a partnership between PUCRS and Hewlett-Packard Brazil. During the period of 2000-2004, I worked with resource management and scheduling for high performance computing environments under supervision of Dr. Cesar A. F De Rose. In that period I developed tools, wrote research papers, and patents. In addition, during my master's research (2002-2004) I worked with simulations for structural Bioinformatics on desktop machines under supervision of Dr. Osmar Norberto de Souza. In 2005, I moved to Sao Paulo to work in the InteGrade's group. This group develops middleware for executing parallel applications on desktop machines. During that period, I was involved with scheduling of Bulk Synchronous Parallel (BSP) applications under supervision of Dr. Alfredo Goldman.

In 2006, I joined GRIDS Lab, at the University of Melbourne, Australia, to pursue my PhD under supervision of Dr. Rajkumar Buyya. My research has been focused on resource management and scheduling of parallel applications, which extends my past background. However, different from my previous research, at this time I am considering environments where quality-of-service is present, and users are paying to achieve it.

I started the year of 2006 reading research papers and technical reports on scheduling of applications with quality-of-service. Moreover, I worked with a master student on the problem of executing message passing applications over Windows/.NET-based desktop grids. This work resulted in two conference papers: "*Carlos Queiroz, Marco A. S. Netto, Rajkumar Buyya. ``Message Passing over Windows-based Desktop Grids". In Proceedings of the ACM/IFIP/USENIX Workshop on Middleware for the Grid (MGC'06). Melbourne, Australia 2006. (2 page poster paper)*" and "*Carlos Queiroz, Marco A. S. Netto, Rajkumar Buyya. ``Message Passing over .NET-based Desktop Grids". In Proceedings of Workshop on Cutting Edge Computing, in conjunction with the 13th IEEE International Conference on High Performance Computing (HiPC'06). Bangalore, India 2006*". I attended these two conferences, Middleware 2006, in Melbourne, Australia, and HiPC 2006, in Bangalore, India, to present the work.

In the second semester of 2006, I studied the resource co-allocation problem and started evaluating the use adaptive requests in utility cluster computing environments. This work resulted in the paper "*Marco A. S. Netto, Rajkumar Buyya. ``Impact of Adaptive Resource Allocation Requests in Utility Cluster Computing Environments". In Proceedings of 7th IEEE International Symposium on Cluster Computing and the Grid. Rio de Janeiro, Brazil 2007",* which I will present in May 2007.

I am currently investigating the scheduling of advance reservations and the management of contracts between users and resource providers for this kind of requests. This study is the base for the resource co-allocation problem, which will be the focus of my research for the second semester of 2007.

Member Self Profile: A-Mukaddim Khan Pathan

I am a second year PhD student in the **Gri**ds Computing and **D**istributed **S**ystems (GRIDS) laboratory, Department of Computer Science and Software Engineering, The University of Melbourne, Australia. I have completed my B.Sc (Hons) in Computer Science and Information Technology (CIT) in 2004 from Islamic University of Technology (IUT), Bangladesh.

I joined GRIDS lab as a Masters by Research student in March, 2006. In the first semester, I have taken a course named "Cluster and Grid Computing", conducted by A/Prof. Rajkumar Buyya, Director of GRIDS Laboratory. This course helped to build the foundation of my research in distributed computing field. In June, 2006 I started working on peering of Content Delivery Networks (CDNs). My work on peering CDNs is a joint collaboration between the GRIDS Laboratory, The University of Melbourne and DSN Laboratory, RMIT University. This project has added an extra dimension to the activities pursued by GRIDS lab and established a pathway to drive innovations in distributed computing, specifically in content networking field. While working as a postgraduate student in GRIDS lab, I got the opportunity to meet renowned international researchers and build collaboration with them. I also served as a program committee member and reviewer of the 5th International Conference on Grid and Cooperative Computing (GCC 2006), Changsha, China. As a researcher of GRIDS lab, I also reviewed papers from recognized and peer-reviewed international conferences and journals. I have been nominated as a local organizer of the ACM/IFIP/USENIX 7th International Middleware Conference, held in Melbourne Australia from 27 November – 1 December, 2006. In April 2007, I applied for Masters to PhD conversion and gave my conversion seminar. On successful completion of the conversion process, I have started pursuing my research as a PhD student.

While working as a postgraduate research student in GRIDS lab, I published research papers in renowned international conferences and technical magazines. Some of my works have also been published as technical reports from GRIDS lab.

In 2007, with the support from GRIDS lab and IEEE Computer Society (through student travel grant), I am going to attend and present my research papers in the 7th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2007), to be held in Rio de Janeiro, Brazil, from 14-17 May, 2007 and in the 16th IEEE International Symposium on High Performance Distributed Computing (HPDC 2007), to be held in Monterey, California, USA, from 25-29 June, 2007.

In the coming years, I hope to uplift the goodwill of GRIDS lab in delivering outstanding outcomes. In this regard, I would like to continue my research following the quality standard established by the GRIDS lab pioneers, through publishing papers in top ranked peer reviewed international journals and conferences.

Member Self Profile: Md Mustafizur Rahman

I am a Masters by Research student under the supervision of Dr. Rajkumar Buyya in Grid Computing and Distributed Systems (GRIDS) Laboratory of The University of Melbourne. In 2006, I was awarded International Postgraduate Research Scholarship (IPRS) and Melbourne International Research Scholarship (MIRS) for my postgraduate study in University of Melbourne and I joined GRIDS lab in March 2006 accordingly.

My interest includes scheduling and optimization of workflow applications, SLA based negotiation and resource allocation. The primary focus of my current research is to develop mechanisms for scheduling and management of Grid workflow applications considering QoS (Quality of Service) guarantee and SLA (Service Level Agreement).

Since I joined GRIDS lab, I tried to gather knowledge and expertise in different areas of Grid Computing. I developed my expertise on Grid Brokering Services such as, Gridbus Service Broker, Enterprise Grid System such as, Alchemi, Grid Simulation Toolkit such as, GridSim, and also Globus Toolkit which has been vastly used for building Grid-based applications. I have simulated different Grid workflow scheduling algorithms being implemented in various Grid projects and evaluated their performances which helped me to get a clear understanding of the workflow scheduling approaches and also has given me the proper direction in my current research.

Recently, I started working on the Australian Research Council (ARC) Discovery Grant project, ”QoS-based Scheduling of e-Research Application Workflows on Global Grids”. To meet QoS requirements of e-Research application workflows, this project aims to develop Grid technologies that support QoS-based scheduling of e-Research application workflows on distributed resources, mechanisms for formulating, negotiating and establishing service level agreements (SLA) with resource providers and also SLA-based allocation and management of Grid resources.

Currently, I am focusing on developing a scheduling algorithm for efficient execution of data intensive workflow applications considering large data movement between the resources on which workflow tasks are mapped and also replicas and other data repositories. When advance reservation technique is used for executing workflow tasks, the introduction of SLA causes failure of successive tasks upon failure of a single task, resulting a huge performance degradation of workflow management system. So I am also investigating for developing a fault-aware scheduling approach for workflows to avoid such problem.

Besides doing my research, in 2006, I was also involved in other activities regarding professional development. In June, I attended “2006 Winter School in Mathematical and Computational Biology” hosted by University of Queensland. In September, I also participated in “8th Melbourne Bioinformatics Course” held in University of Melbourne. I have become student member of ACM, IEEE and IEEE Computer Society. I was a student volunteer of “ACM/IFIP/USENIX 7th International Middleware Conference” organized in Melbourne, November 2006.

Member Self Profile: James Broberg

I work in the GRIDS Laboratory as a Research Fellow (Grid Computing). My interests include research, design, modelling and analysis of distributed and grid computer systems. In particular, I utilise queuing theory and probabilistic models, as well as event-based (discrete) or rate-based (fluid) simulation models, to analyse the performance of these systems. I am also interested in the linear and non-linear optimisation problems that arise from attempting to maximise the performance and utility of such systems.

Since joining the GRIDS Laboratory in January 2007 I have actively contributed to work on Peering of Content Delivery Networks (CDNs) (http://www.gridbus.org/cdn). By enabling coordinated and cooperative content delivery between existing CDNs we will allow a CDN provider to rapidly "scale-out" to meet both flash crowds and anticipated increases in demand. Improved economies of scale, in terms of cost effectiveness and performance for both providers and end-users, can be achieved by leveraging existing infrastructure provided by other CDNs.

However, enabling VOs of CDNs (VCDNs) will require fundamental research to be undertaken to address the core theoretical problems of measuring and disseminating load information, performing request assignment and redirection, and enabling content replication amongst VCDNs on a geographically distributed "Internet" scale. These issues are deeply interrelated and co-dependent for a single CDN. However, they must now be considered in a coordinated and cooperative manner amongst many participating CDNs within a VO, whilst satisfying the complex multi-dimensional constraints placed on each individual provider. We have already surveyed the problems faced in such VCDNs with several motivating case studies[14], and provided initial peering architectures[15][16].

My main focus in the GRIDS Laboratory is performing research into utility driven distributed and grid systems, under the auspices of the DEST funded grant, "The Utility Gird Project: Autonomic and Utility-Oriented Global Grids for Powering Emerging e-Research Applications". We are currently evaluating the current state of the art in market-based utility computing efforts that are happening worldwide, examining efforts into price setting and negotiation, grid economy management and utility-driven scheduling and resource allocation.

---

[14] Rajkumar Buyya, Al-Mukaddim Khan Pathan, James Broberg, and Zahir Tari. A Case for Peering of Content Delivery Networks, IEEE Distributed Systems Online, vol. 7, no. 10, 2006, art. no. 0610-o10003, Los Alamitos, CA, USA.

[15] Al-Mukaddim Khan Pathan, Rajkumar Buyya, James Broberg, and Kris Bubendorfer, Economy-based Content Replication for Peering Content Delivery Networks (extended version), Technical Report, GRIDS-TR-2006-21, Grid Computing and Distributed Systems Laboratory, University of Melbourne, Australia, 04 December, 2006.

[16] Al-Mukaddim Khan Pathan, James Broberg, Kris Bubendorfer, Kyong Hoon Kim, and Rajkumar Buyya, An Architecture for Virtual Organization (VO)-based Effective Peering of Content Delivery Networks, UPGRADE-CN'07, In Proceedings of the 16th IEEE International Symposium on High Performance Distributed Computing (HPDC 2007), Monterey Bay, California, USA, 25-29 June, 2007.

I am actively working on the problem of maximising utility in market-driven distributed computing systems. In such systems, users have jobs that need to be processed, for which they are willing to proportionally compensate a provider to perform depending on the utility they receive. Rather than dealing with service providers directly, users facilitate access through brokers who can virtualise and make available the resources of multiple service providers, achieving greater economies of scale, improving throughput and reducing cost.

We approach this problem by modelling the system as an adaptation of the classical multicommodity flow problem to the market-based, utility driven problem. In a market-driven distributed system, customers compete against each other by assigning a utility value or function to their jobs in an effort to have them processed successfully in the face of highly contested and constrained resources. Brokers and service providers co-ordinate in order to maximise the utility they gain, often choosing to process the jobs that will earn them the highest revenue or yield with respect to the resources required.

For our system to be effective, we need a highly distributed solution, where each node can operate independently whilst reaching a near-optimal global state where each participant is satisfied. Distributed solutions to the multicommodioty flow problem has been successfully adapted to a variety of problem domains, including maximising lifetime routing in wireless ad-hoc and sensor networking, and enabling distributed resource allocation in stream processing systems. I am currently vigorously refining a distributed solution that maximises overall utility for participants in market-driven distributed computing systems.

Moments with Visitors and International Hosts

with Prof. Chris Johnson form Utah

Microsoft Award Winning MEDC students & Nigel Watson

Albacete, Spain, 2006: with general chair

Albacette, Spain, 2006: during talk

Tehran, Iran: with general chair

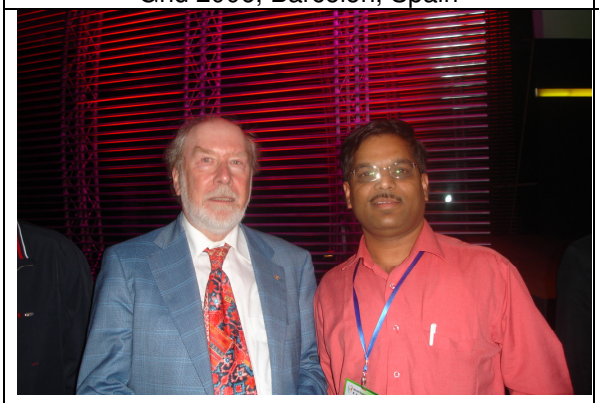
During talk at CSICC 2006

Seminar at National University of Defence Technology (NUDT), Changsha, China

With NUDT Students

Grid 2006, Barcelon, Spain

Massey University, New Zealand

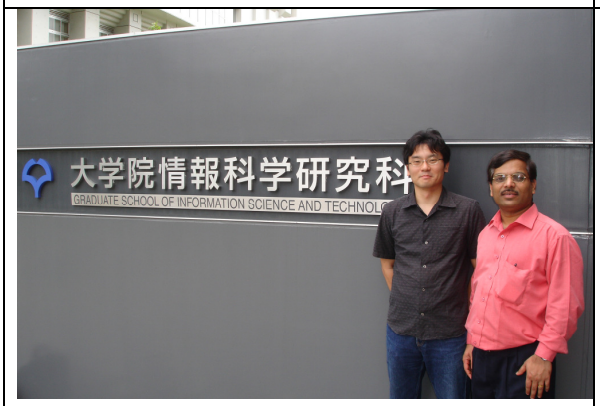


Prof. Nicholas Wirth (Pascal language inventor) at Microsoft Faculty Summit

Microsoft, Beijing, China

Obcom 2006, Vellore, India

ADCOM 2006, Surathkal, India



with Susumu Date at Osaka University

e-Science Congress, Santiago, Chile

CCGrid 2006 Steering Committee Meeting in Singapore

Destination Grid!

A Note on Grid Computing into the Future

[A copy of message sent to Grid Infoware as a community update note]

Dear Colleagues,

I would like to share some updates on Grid computing area and new activities initiated within GRIDS Lab/Gridbus Project at Melbourne.

1. In the recent past, world-wide several efforts have been initiated to enhance grid computing with capabilities that support Quality of Services, service level agreements (SLA), utility-oriented allocation of Grid resources to SLA dynamically. Even European Union has put together a report on "Service-Oriented Knowledge Utility (SOKU): Vision and Research Directions 2010 and Beyond" clearly signaling their intension to support research around it as these are fundamental for wide-scale adoption of Grid computing in enterprise applications.

2. Fortunately, this area has been key focus on our Gridbus Project since its initiation in 2002. I happen to present a keynote talk at 14th International Conference on Advanced Computing and Communications in which I have shared key outcomes of Gridbus project. The title of my talk was "Gridbus Middleware for Utility Grids: Building Autonomic and Market-Oriented Global Grids for Delivering IT Services as the 5th Utility". Those of you who have not attended this conference, you may may want to walk through my slides:
http://www.gridbus.org/talks/Gridbus-ADCOM2006-Keynote.ppt

3. Gridbus Project is going to continue push heavily in this space as we have secured funds for Australian Research Council (ARC) and Australian Department of Science, Education and Training (DEST). Details on these two projects are included below.

GRIDS Lab/Gridbus's New Projects from 2007-2009

Discovery Project: funded by Australian Research Council

Project Title:

QoS-based Scheduling of e-Research Application Workflows on Global Grids

Project Summary:
The emerging e-Research paradigm enables researchers from different disciplines and organisations to engage in collaborative scientific investigation. They need to share geographically distributed resources owned by different organisations. e-Research applications need to negotiate with resource providers for guarantees on access time, duration and level of quality of service (QoS). To meet these requirements, this project aims to develop technologies that support (a) QoS-based scheduling of e-Research application workflows on distributed resources, (b) mechanisms for negotiating service level

agreements (SLA) with resource providers, and (c) a system that supports SLA-based allocation and management of resources.

International Science Linkage Project: funded by Australian Department of Science, Education and Training

Project Title:
The Utility Grid Project: Autonomic and Utility-Oriented Global Grids for Powering Emerging e-Research Applications.

Project Summary:
Grid computing is emerging as an enabler for the creation of global Cyberinfrastructure for e-Research applications and is recognised as one of the top five emerging technologies that will have a major impact on the quality of science and society over the next 20 years. This project will link Australian researchers with international researchers through two EU FP6 projects: CoreGrid and CatNets. The project is aimed at enhancing the scope and depth of Australian R&D in Grid computing and e-Research; establishing linkages to enable the leveraging of the capabilities and resources of both Australian and international partners; and developing grid technologies that improve agility and utility of national and international Cyberinfrastructure powering e-Research applications.

BTW, if you are still wondering about "e-Research" word, it is an Australian term for "e-Science" or Grid applications.

4. In addition to the above two projects, GRIDS Lab has has expanded its research areas such as (a) Content Delivery Networks (CDN) and (2) InterGrid - Overlay Networks for Peering between Islands of Grids. Please check out our websites for:
 CDN: http://www.gridbus.org/cdn/
 InterGrid: http://www.gridbus.org/intergrid/
These are large initiatives and should present significant opportunity for creating new collaborative projects with international colleagues.

If any of you are interested in exploring these topics or have already been exploring and wants to collaborate with us, please let me know.

Cheers
Raj
April 5, 2007