Grid Computing and Distributed Systems Laboratory and the Gridbus Project



Annual Report - 2008

By

Dr. Rajkumar Buyya

Associate Professor and Reader



Department of Computer Science and Software Engineering

The University of Melbourne, Australia

1. 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 2008, which has been a fantastic year for GRIDS Lab and its members. The GRIDS Lab continues to be one of the leading and



innovative research groups in the area of Grid computing and distributed systems nationally and internationally. The highlights of research activities and outcomes in 2008 are:

- The Lab successfully launched two large research projects: (i) ARC (Australian Research Council) Discovery Project "QoS-based Scheduling of e-Research Application Workflows on Global Grids" and (ii) DIISR International Science Linkage project on "Autonomic and Utility-oriented Global Grids for Powering Emerging E-Research Applications".
- The Lab successfully transferred IP of our Cloud software technology to Manjrasoft, a spin-off company of the University of Melbourne for successful commercialisation.
- Members of GRIDS Lab have authored 39 publications, which include 10 journal papers, 22 conference papers, and 3 edited books/conference proceedings.
- The Lab's flagship Gridbus Project has released "open source" Grid middleware technologies which are used by several researchers and users in academia and industries around the globe.
- Members have presented over 35 invited talks that include 4 keynotes delivered at international conferences held in Canada, China, India, and Bangladesh.
- The Lab successfully hosted research activities of over 20 scholars: 8 research students (most of them were PhD students), 5 Research Fellows (at PostDoc level), 3 Software Engineers, and couple of Masters/honours students. Two Ph.D students have graduated.
- The Lab Director and many of its members have been recognised for their outstanding contribution to Australian research with international significance "Chris Wallace Outstanding Researcher Award 2008" from the CORE (Computing Research and Education Association of Australasia); and "Dream Large Knowledge Transfer Award" from Provost, University of Melbourne.
- The Lab housed several (short and long term) international visitors (academic and PhD students) from China, India, USA, Germany, and Austria.
- Received "Best Paper Award" from the 16th International Conference on Advanced Computing and Communications (ADCOM 2008, Chennai, India), Dec. 2008. Authors: Saurabh Garg, Pramod Konugurthi, and Rajkumar Buyya; Paper: A Linear Programming Driven Genetic Algorithm for Meta-Scheduling on Utility Grids.
- Published an edited book on "Content Delivery Networks", Springer.
- Members of the Lab have led community efforts by (a) involving in the organisation of conferences (e.g., CCGrid 2008 in Lyon, France and ADCOM 2008, Chennai, India), (b) served on the Steering Committee of 6 international conferences and (c) served as the Chair of the Advisory Board of the IEEE Technical Committee on Scalable Computing.

The Lab has secured one new grant for future activities from ARC: Linkage Project on SLA-Oriented Resource Allocation for Cloud Computing and Linkage Project with Platform as an industry partner.

The Lab is always looking for talented, motivated, and dedicated "young" students and researchers to join its team. Please feel free to contact me with your ideas!

Associate Professor Rajkumar Buyya, PhD Director, Grid Computing and Distributed Systems (GRIDS) Laboratory Department of Computer Science and Software Engineering The University of Melbourne, Australia Web : gridbus.org

2. The Team

Director:

• Dr.Rajkumar Buyya, Associate Professor and Reader

Research Staff:

- Dr. Srikumar Venugopal
- Dr. Chao Jin
- Dr. James Broberg
- Mr. Xingchen Chu
- Dr. Christian Vecchiola
- Dr. Alexandre di Costanzo
- Mr. Tom Kobialka

PhD Students

- Mr. Anthony Sulistio
- Mr. Chee Shin Yeo
- Mr. Rajiv Ranjan
- Mr. Marcos Assunção
- Mr. Marco Netto
- Mr. Mukaddim Pathan
- Mr. Mustafizur Rahman
- Mr. Saurabh Garg
- Mr. Suraj Pandey
- Mr. William Voorsluys
- Ms. Charity Laplap

Masters by Research Students

- Khaled Talukder
- Michael Mattess

Collaborators

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

3. Competitive Grants Funded Projects and Programs

Australian Research Council (ARC)

- R. Buyya, QoS-based Scheduling of e-Research Application Workflows on Global Grids, Discovery Project, Australian Research Council, Australia, 2007-2009. Amount: \$319,000.
- R. Buyya, A Novel Software System for .NET-based Enterprise Grid Computing, Linkage Project, Australian Research Council (ARC) and Microsoft Corporation, Australia, 2007-2010. Amount: \$395,000 (ARC: \$265,000 and Microsoft: \$130,000).
- R. Buyya and J. Abawajy, InterGrid: Peering Architecture and Policies for Internetworking Disparate Grids, Discovery Project, Australian Research Council (ARC), Australia, 2008-2010. Amount: \$216,000.
- J. Broberg and Z. Tari, Coordinated and Cooperative Load Sharing between Content Delivery Networks, Discovery Project, Australian Research Council (ARC), Australia, 2008-2010. Amount: \$315,000
- 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, Australia, 2004 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 (<u>ARC</u>), Australia, 2004/05 to 2008/09. Amount: \$2,250,000.
- M. Palaniswami, R. Kotagiri, R. Tucker, I. Atkinson, P. Pathirana, C. Leckie, P. Mendis, R. Buyya, M. Duckham, S. Halgamuge, G. Woods, L. Kulik, E. Tanin, S. Dey, B.N. Vo, K. Smith-Miles, M. Zukerman, BigNet A Distributed Wireless Sensor Network Testbed, Linkage Infrastructure, Equipment and Facilities (LIEF) grant, Australian Research Council (ARC), Australia, 2008. Amount: \$200,000.

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, 2005-2012.
- R. Buyya (project manager) and team, *The Utility Grid Project: Autonomic and Utilityoriented 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

- S. O'Leary, R Dowell, B. Pyman, P. Harris, G. Kennedy, L. Wise, A. Goodwin, N. Eizenberg, C. Briggs, E. Reynolds, A. Smith, M. Galea, R. Buyya, E. Kazmierczak, and L. Irving, "Haptic and 3D Visual Immersive Environments", SRIF (Strategic Research Infrastructure Fund). The University of Melbourne, 2006-2008. Amount: \$500,000.
- J. Ellershaw, M. Duckham, A. Kealy, S. Winter, R. Tucker, J. Papandriopoulos, A. Overmars, R. Kotagiri, R. Buyya, L. Kulik, E. Tanin, P. Mendis, H. Malano, D. Smith, "Sensor Network Student Laboratory and Research Facility", A. E. Rowden White Foundation Grant, 2007-2008. Amount: \$100,000
- S. Venugopal and J. Broberg, Adaptive Provisioning and Allocation for Shared Computing Resources using Virtual Machines, University of Melbourne Early Career Researcher Grants Scheme, 2008. Amount: \$30,000.

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.

4. Publications

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

Year Publication Type	2002	2003	2004	2005	2006	2007	2008
Books/Proceedings Edited	1	1	1	1	5	4	3
Journal Papers	6	1	4	5	6	4	10
Book Chapters	1	0	0	4	4	2	4
Conference Papers	4	7	9	16	15	24	22
Magazine/Other Articles	0	0	1	2	4	2	0
Total	12	9	15	28	34	36	39

Books

1. Rajkumar Buyya, Mukaddim Pathan and Athena Vakali (eds.), <u>Content Delivery Networks</u>, ISBN: 978-3-540-77886-8, Springer, Berlin, Germany, 2008.

Book Chapters

- Jia Yu, Rajkumar Buyya, and Kotagiri Ramamohanarao, <u>Workflow Scheduling Algorithms</u> for Grid Computing, Metaheuristics for Scheduling in Distributed Computing Environments, F. Xhafa and A. Abraham (eds), ISBN: 978-3-540-69260-7, Springer, Berlin, Germany, 2008.
- 3. Mukaddim Pathan, Rajkumar Buyya, and Athena Vakali, "CDNs: State of the Art, Insights, and Imperatives", Content Delivery Networks, R. Buyya, M. Pathan, and A. Vakali (Eds.), ISBN: 978-3-540-77886-8, Springer-Verlag, Germany, 2008.
- 4. Mukaddim Pathan and Rajkumar Buyya, and Athena Vakali, "A Taxonomy of CDNs", Content Delivery Networks, R. Buyya, M. Pathan, and A. Vakali (Eds.), ISBN: 978-3-540-77886-8, Springer-Verlag, Germany, 2008.
- 5. Mukaddim Pathan, Rajkumar Buyya, and James Broberg, "Internetworking of CDNs", Content Delivery Networks, R. Buyya, M. Pathan, and A. Vakali (Eds.), ISBN: 978-3-540-77886-8, Springer-Verlag, Germany, 2008.

Proceedings Edited

- 6. Thierry Priol, Laurent Lefevre, and Rajkumar Buyya, *Proceedings of the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008, Lyon, France)*, ISBN: 978-0-7695-3156-4, IEEE CS Press, Los Alamitos, CA, USA.
- 7. Ruppa Thulasiram, Thamarai Selvi, and Rajkumar Buyya, *Proceedings of the 16th International Conference on Advanced Computing and Communication (ADCOM 2008, Dec. 14-17, 2008, Chennai, India)*, ISBN 978-1-4244-2963-9, IEEE Press, New York, USA.

Journal Papers

- Srikumar Venugopal and Rajkumar Buyya, <u>An SCP-based Heuristic approach for</u> <u>Scheduling Distributed Data-Intensive Applications on Global Grids</u>, Journal of Parallel and Distributed Computing, Volume 68, No. 4, Pages: 471-487, ISSN: 0743-7315, Elsevier Press, Amsterdam, The Netherlands, April 2008.
- Hussein Gibbins and Rajkumar Buyya, <u>Gridscape II: An Extensible Grid Monitoring Portal</u> <u>Architecture and its Integration with Google Maps</u>, International Journal of Parallel, Emergent and Distributed Systems, Volume 23, No. 2, Pages: 153-170, ISSN: 1744-5760, Taylor & Francis Group, UK, April 2008.
- Rajiv Ranjan, Aaron Harwood and Rajkumar Buyya, <u>A Case for Cooperative and Incentive-Based Federation of Distributed Clusters</u>, Future Generation Computing Systems, Volume 24, No. 4, Pages: 280-295, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands, April 2008.
- 11. Marcos Dias de Assunção, Rajkumar Buyya and Srikumar Venugopal, <u>InterGrid: A Case</u> <u>for Internetworking Islands of Grids</u>, Concurrency and Computation: Practice and Experience, Volume 20, No. 8, Pages: 997-1024, ISSN: 1532-0626, Wiley Press, New York, USA, June 10, 2008.
- 12. Xingchen Chu, Andrew Lonie, Peter Harris, Randall Thomas, and Rajkumar Buyya, <u>A</u> <u>Service-Oriented Grid Environment for Integration of Distributed Kidney Models and</u> <u>Resources</u>, Concurrency and Computation: Practice and Experience, Volume 20, No. 9, Pages: 1095-1111, ISSN: 1532-0626, Wiley Press, New York, USA, June 25, 2008.
- 13. Hailong Sun, Jinpeng Huai, Yunhao Liu and Rajkumar Buyya, <u>RCT: A Distributed Tree</u> <u>for Supporting Efficient Range and Multi-attribute Query in Grid Computing</u>, Future Generation Computer Systems, Volume 24, No. 7, Pages: 631-643, ISSN: 0167-739X, Elsevier Science, Amsterdam, The Netherlands, July 2008.
- 14. Srikumar Venugopal, Krishna Nadiminti, Hussein Gibbins and Rajkumar Buyya, <u>Designing a Resource Broker for Heterogeneous Grids</u>, Software: Practice and Experience, Volume 38, Issue 8, Pages: 793-825, ISSN: 0038-0644, Wiley Press, New York, USA, July 10, 2008.
- 15. James Broberg, Srikumar Venugopal, Rajkumar Buyya, <u>Market-oriented Grids and Utility</u> <u>Computing: The state-of-the-art and future directions</u>, Journal of Grid Computing, Volume 6, Number 3, Pages: 255-276, ISSN: 1570-7873, Springer Verlag, Germany, Sept. 2008.
- Rajiv Ranjan, Aaron Harwood, Rajkumar Buyya, <u>Peer-to-Peer Based Resource</u> <u>Discovery in Global Grids: A Tutorial</u>, IEEE Communications Surveys and Tutorials, Volume 10, Number 2, Pages: 6-33, ISSN: 1553-877X, IEEE Communications Society Press, USA, 2008.
- Anthony Sulistio, Uros Cibej, Srikumar Venugopal, Borut Robic and Rajkumar Buyya, <u>A</u> <u>Toolkit for Modelling and Simulating Data Grids: An Extension to GridSim</u>, Concurrency and Computation: Practice and Experience, Volume 20, Number 13, Pages: 1591 - 1609, ISSN: 1532-0626, Wiley Press, New York, USA, Sept. 10, 2008.

Conference Papers

- Rajkumar Buyya and Anthony Sulistio, <u>Service and Utility Oriented Distributed Computing</u> <u>Systems: Challenges and Opportunities for Modeling and Simulation Communities</u>, Keynote Paper, Proceedings of the 41th Annual Simulation Symposium (ANSS-41, IEEE CS Press, Los Alamitos, CA, USA), April 14-16, 2008, Ottawa, Canada.
- Agustin Caminero, Anthony Sulistio, Blanca Caminero, Carmen Carrion, and Rajkumar Buyya, <u>Simulation of Buffer Management Policies in Networks for Grids</u>, Proceedings of the 41th Annual Simulation Symposium (ANSS-41, IEEE CS Press, Los Alamitos, CA, USA), April 14-16, 2008, Ottawa, Canada.
- 20. Rajiv Ranjan, Mustafizur Rahman, and Rajkumar Buyya, <u>A Decentralized and</u> <u>Cooperative Workflow Scheduling Algorithm</u>, Proceedings of the 8th IEEE International

Symposium on Cluster Computing and the Grid (CCGrid 2008, IEEE CS Press, Los Alamitos, CA, USA), May 19-22, 2008, Lyon, France.

- 21. Anthony Sulistio, Kyong Hoon Kim, and Rajkumar Buyya, <u>Managing Cancellations and</u> <u>No-shows of Reservations with Overbooking to Increase Resource Revenue</u>, Proceedings of the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008, IEEE CS Press, Los Alamitos, CA, USA), May 19-22, 2008, Lyon, France.
- 22. Suraj Pandey and Rajkumar Buyya, <u>Scheduling of ScientificWorkflows on Data Grids</u>, TCSC Doctoral Symposium, Proceedings of the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008, IEEE CS Press, Los Alamitos, CA, USA), May 19-22, 2008, Lyon, France.
- Mustafizur Rahman and Rajkumar Buyya, <u>An Autonomic Workflow Management System</u> for Global Grids, TCSC Doctoral Symposium, Proceedings of the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008, IEEE CS Press, Los Alamitos, CA, USA), May 19-22, 2008, Lyon, France.
- 24. Christoph Reich, Kris Bubendorfer, and Rajkumar Buyya, <u>An Autonomic Peer-to-Peer</u> <u>Architecture for Hosting Stateful Web Services</u>, Proceedings of the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008, IEEE CS Press, Los Alamitos, CA, USA), May 19-22, 2008, Lyon, France.
- 25. Srikumar Venugopal, Xingchen Chu, and Rajkumar Buyya, <u>A Negotiation Mechanism for</u> <u>Advance Resource Reservation using the Alternate Offers Protocol</u>, Proceedings of the 16th International Workshop on Quality of Service (IWQoS 2008, IEEE Communications Society Press, New York, USA), June 2-4, 2008, Twente, The Netherlands.
- Khaled Talukder, Michael Kirley and Rajkumar Buyya, <u>A Pareto Following Variation</u> <u>Operator for Fast-Converging Multiobjective Evolutionary Algorithms</u>, Proceedings of the 10th Annual Genetic and Evolutionary Computation Conference (<u>GECCO-2008</u>, ACM Press, New York, USA), July 12-16, 2008, Atlanta, USA.
- 27. Marco Netto and Rajkumar Buyya, <u>Rescheduling Co-Allocation Requests based on</u> <u>Flexible Advance Reservations and Processor Remapping</u>, Proceedings of the 9th IEEE International Conference on Grid Computing, (Grid 2008, IEEE CS Press, Los Alamitos, CA, USA), Sept. 29-Oct. 1, 2008, Tsukuba, Japan.
- Rajkumar Buyya, Chee Shin Yeo, and Srikumar Venugopal, <u>Market-Oriented Cloud</u> <u>Computing: Vision, Hype, and Reality for Delivering IT Services as Computing Utilities,</u> Keynote Paper, Proceedings of the 10th IEEE International Conference on High Performance Computing and Communications (HPCC 2008, IEEE CS Press, Los Alamitos, CA, USA), Sept. 25-27, 2008, Dalian, China.
- 29. Mukaddim Pathan, Christian Vecchiola, Rajkumar Buyya, <u>Load and Proximity Aware</u> <u>Request-Redirection for Dynamic Load Distribution in Peering CDNs</u>, Proceedings of 16th International Conference on Cooperative Information Systems (CoopIS 2008, LNCS 5331, 62-81pp, Springer, Berlin, Germany), Nov. 12-14, 2008, Monterrey, Mexico.
- Ivona Brandic, Dejan Music, Schahram Dustdarm, Srikumar Venugopal, Rajkumar Buyya, <u>Advanced QoS Methods for GridWorkflows Based on Meta-Negotiations and SLA-</u> <u>Mappings</u>, Proceedings of the 3rd Workshop on Workflows in Support of Large-Scale Science, in conjunction with SC 2008 Conference, Nov. 17, 2008, Austin, TX, USA.
- 31. James Broberg, Rajkumar Buyya and Zahir Tari, <u>Creating a 'Cloud Storage' Mashup for</u> <u>High Performance, Low Cost Content Delivery</u>, Second International Workshop on Web APIs and Services Mashups (Mashups'08), In Proceedings of The Sixth International Conference on Service-Oriented Computing Workshops (LNCS 5472, Springer, Germany), Dec. 1-5, 2008, Sydney, Australia.
- 32. Marcos Dias de Assuncao and Rajkumar Buyya, <u>A Cost-Aware Resource Exchange</u> <u>Mechanism for Load Management across Grids</u>, Proceedings of the 14th IEEE International Conference on Parallel and Distributed Systems (ICPADS 2008, IEEE CS Press, Los Alamitos, CA, USA), Dec. 8-10, 2008, Melbourne, Australia.
- 33. Saurabh Kumar Garg, Srikumar Venugopal, and Rajkumar Buyya, <u>A Meta-scheduler with</u> <u>Auction Based Resource Allocation for Global Grids</u>, Proceedings of the 14th IEEE International Conference on Parallel and Distributed Systems (ICPADS 2008, IEEE CS Press, Los Alamitos, CA, USA), Dec. 8-10, 2008, Melbourne, Australia.

- Chao Jin, Christian Vecchiola, and Rajkumar Buyya, <u>MRPGA: An Extension of</u> <u>MapReduce for Parallelizing Genetic Algorithms</u>, Proceedings of the 4th IEEE International Conference on e-Science, (e-Science 2008, IEEE CS Press, Los Alamitos, CA, USA), Dec. 10-12, 2008, Indianapolis, Indiana, USA.
- 35. Mukaddim Pathan and Rajkumar Buyya, <u>Performance Models for Peering Content</u> <u>Delivery Networks</u>, Proceedings of 16th IEEE International Conference on Networks (ICON 2008, IEEE Press, New Jersey, USA), Dec. 12-14, 2008, New Delhi, India.
- 36. Chao Jin, Jayavardhana Gubbi, Rajkumar Buyya, and Marimuthu Palaniswami, <u>Jeeva:</u> <u>Enterprise Grid-enabled Web Portal for Protein Secondary Structure Prediction</u>, Proceedings of the 16th International Conference on Advanced Computing and Communication (ADCOM 2008, IEEE Press, New York, USA), Dec. 14-17, 2008, Chennai, India.
- 37. Saurabh Garg, Pramod Konugurthi, and Rajkumar Buyya, <u>A Linear Programming Driven Genetic Algorithm for Meta-Scheduling on Utility Grids</u>, Proceedings of the 16th International Conference on Advanced Computing and Communication (ADCOM 2008, IEEE Press, New York, USA), Dec. 14-17, 2008, Chennai, India.
- Ivona Brandic, Srikumar Venugopal, Michael Mattess, and Rajkumar Buyya, Towards a Meta-Negotiation Architecture for SLA-Aware Grid Services, Proceedings of the HiPC 2008 International Workshop on Service-Oriented Engineering and Optimization, December 17, 2008, Bangalore, India.
- Marcos Dias de Assuncao and Rajkumar Buyya, <u>Performance Analysis of Multiple Site</u> <u>Resource Provisioning: Effects of the Precision of Availability Information</u>, Proceedings of the 15th IEEE International Conference on High Performance Computing (HiPC 2008, Springer, Berlin, Germany), Dec. 17-20, 2008, Bangalore, India.

5. Invited Presentations and Outreach

Keynote Talks at International Conferences

- 1. Service and Utility Oriented Distributed Computing Systems: Challenges and Opportunities for Modeling and Simulation Communities, 41th Annual Simulation Symposium (ANSS-41), April 14-16, 2008, Ottawa, Canada.
- 2. Market-Oriented Cloud Computing: Vision, Hype, and Reality for Delivering IT Services as Computing Utilities, 10th IEEE International Conference on High Performance Computing and Communications (HPCC 2008), Sept. 25-27, 2008, Dalian, China.
- 3. Utility-Oriented Cloud Computing: A Vision, Hype, and Reality, 5th International Conference on Distributed Computing and Internet Technologies (ICDCIT 2008), December 10-12, 2008, New Delhi, India.
- 4. Utility-Oriented Grid Computing and the Gridbus Middleware, 11th International Conference on Computer and Information Technology (ICCIT 2008), Dec. 25-27, 2008, Khulna, Bangladesh.

Seminars

- 1. Utility-Oriented Grid Computing and the Gridbus Middleware, Australian National University, Canberra, Australia, Jan. 21, 2008.
- 2. Utility-Oriented Grid Computing and the Gridbus Middleware, Macquarie University, Sydney, Australia, Jan. 25, 2008.
- 3. Grid Computing and the Gridbus Middleware, Swinburne University of Technology, Melbourne, Australia, March 28, 2008.
- 4. Utility-Oriented Grid Computing and the Gridbus Middleware, Carlton University, Ottawa, Canada, April 16, 2008.
- 5. Market-Oriented Grid Computing and the Gridbus Middleware, McGill University, Montreal, Canada, April 17, 2008.
- 6. Market-Oriented Grid Computing and the Gridbus Middleware, Argonne National Laboratory/University of Chicago, Chicago, USA, April 18, 2008.
- 7. Cloud Computing: A Vision, Hype, and Reality, The University of Innsbruck, Innsbruck, Austria, Aug. 13, 2008.
- 8. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, The University of Innsbruck, Innsbruck, Austria, Aug. 14, 2008.
- 9. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Vienna University of Technology, Vienna, Austria, Aug. 18, 2008.
- 10. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, University of Paris-Sud/INRIA, Paris, France, Aug. 20, 2008.
- 11. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, University of Karlsruhe, Karlsruhe, Germany, Aug. 25, 2008.
- 12. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, SAP Research, Karlsruhe, Germany, Aug. 25, 2008.
- 13. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, University of Mannheim, Mannheim, Germany, Aug. 29, 2008.
- 14. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, University of Stuttgart, Stuttgart, Germany, Sept. 1, 2008.
- 15. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, University of Rome II, Tor Vergata, Rome, Italy, Sept. 4, 2008.
- Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Information Science and Technologies Institute, Italian National Research Council, Pisa, Italy, Sept. 8, 2008.
- 17. Market-Oriented Cloud Computing: A Vision, Hype, and Reality, Barcelona Supercomputing Center, Barcelona, Spain, Sept. 12, 2008.

- 18. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Universidad Politécnica de Madrid, Madrid, Spain, Sept. 18, 2008.
- 19. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Universidad de Castilla-La Mancha, Albacete, Spain, Sept. 22, 2008.
- 20. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Technische Universität München, Munich, Germany, Sept. 24, 2008.
- 21. Market-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, The University of Hong Kong, Hong Kong, China, Sept. 30, 2008.
- 22. Cloud Computing: A Vision, Hype, and Reality, IBM India Research Lab, New Delhi, India, Dec. 12, 2008.
- 23. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Tata Consultancy Services (TCS), Chennai, India, Dec. 16, 2008.
- 24. Recent Advances in Parallel and Distributed Computing, MIT College of Engineering, Pune, India, Dec. 17, 2008.
- 25. Recent Advances in Parallel and Distributed Computing, M S Ramaiah Institute of Technology, Bangaluru, India, Dec. 18, 2008.
- 26. Cloud Computing: A Vision, Hype, and Reality, Wipro Technologies, Bangaluru, India, Dec. 18, 2008.
- 27. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Supercomputer Education and Research Centre (SERC), Indian Institute of Science (IISc), Bangalure, India, Dec. 19, 2008.
- 28. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, Dec. 22, 2008.
- 29. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, Dhaka University, Dhaka, Bangladesh, Dec. 23, 2008.
- 30. Recent Advances in Parallel and Distributed Computing, Indian Statistical Institute (ISI), Kolkata, India, Dec. 29, 2008.
- 31. Utility-Oriented Cloud and Grid Computing: A Vision, Hype, and Reality, KIIT University, Bhubaneswar, India, Dec. 31, 2008.

Conference Tutorials

- 1. Market-Oriented Grid Computing and the Gridbus Middleware, 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008), May 19-22, 2008, Lyon, France.
- 2. Market-Oriented Grid Computing and the Gridbus Middleware, 4th IEEE International Conference on e-Science, Indianapolis, USA, Dec. 7-12, 2008.
- 3. Content Delivery Networks, 16th IEEE International Conference on Networks (ICON 2008), Dec. 12-14, 2008, New Delhi, India.
- 4. Market-Oriented Grid Computing and the Gridbus Middleware, 16th International Conference on Advanced Computing and Communications (ADCOM 2008), Dec. 14-17, 2008, Chennai, India.
- 5. Content Delivery Networks: Scaling and Enhancing the Web, 16th International Conference on Advanced Computing and Communications (ADCOM 2008), Dec. 14-17, 2008, Chennai, India.

6. Community Services (of Dr. Buyya)

IEEE Computer Society

1. Chair of Advisory Board, 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

- Chair, CCGrid conference series: IEEE/ACM International Symposium on Cluster Computing and the Grid (CCGrid): CCGrid 2001, Brisbane, Australia; CCGrid 2002, Berlin, Germany; CCGrid 2003, Tokyo, Japan; CCGrid 2004 in Chicago, USA; CCGrid 2005, UK; CCGrid 2006, Singapore; CCGrid 2007, Brazil; CCGrid 2008, Lyon, France.
- 2. Co-Chair, International Conference on e-Science(e-Science) series, 2005- to date.
- 3. Member, IEEE/ACM Supercomputing (SCxy) Conference, USA, 2005-2008.
- 4. Member, IEEE International Conference on Cluster Computing (ClusterXY), 1999-to date.
- 5. Member, International Symposium on Computer Architecture and High Performance Computing, Brazil, 2005-to date.
- 6. Member, IEEE/ACM International Conference on Grid Computing (GRIDxy), 2000-to date.

Conference Chair

1. Co-Chair, 16th International Conference on Advanced Computing and Communication (ADCOM 2008), Dec. 14-17, 2008, Chennai, India.

Misc. Services Chair

1. Publications Chair, 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008), May 19-22, 2008, Lyon, France.

Technical Program Committee Memberships

- 1. 15th IEEE International Conference on High Performance Computing (HiPC 2008), December 17-20, 2008, Bangalore, India.
- 2. 6th International Symposium on Parallel and Distributed Processing Applications (ISPA 2008), Dec. 10-12, 2008, Sydney, Australia.
- 3. 20th International Symposium on Computer Architecture and High Performance Computing (SBAC-PAD 2008), October 29-Nov. 1, 2008, Campo Grande, Brazil.
- 4. 9th IEEE/ACM International Conference on Grid Computing (Grid 2008), September 29 October 1, 2008, Tsukuba, Japan.

- 5. 10th IEEE International Conference on High Performance Computing and Communications (HPCC 2008), September 25-27, 2008, DaLian, China.
- 6. 37th International Conference on Parallel Processing (ICPP 2008), September 8-12, 2008, Portland, Oregon, USA.
- 7. 7th International Conference on Distributed and Parallel Systems, September 3-5, 2008, Debrecen, Hungary.
- 8. 5th IEEE International Conference on Services Computing (SCC 2008), July 8-11, 2008, Honolulu, Hawaii, USA.
- 9. 8th International Conference on Computational Science and Its Applications (ICCSA 2008), June 30- July 3, 2008, Perugia, Italy.
- 10. 23rd Open Grid Forum (OGF 23) Conference, June 2-6, 2008, Barcelona, Spain.
- 11. 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008), May 2008, Lyon, France.
- 12. 9th International Symposium on Parallel Architectures, Algorithms, and Networks (I-SPAN 2008), May 7-9, 2008, Sydney, Australia.
- 13. 17th International Heterogeneity in Computing Workshop (HCW 2008), April 14, 2008, Miami, Florida.
- 14. 6th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA 2008), March 31 April 4, 2008, Doha, Qatar.
- 15. 2008 International Workshop on Multi-Core Computing Systems (MuCoCoS'08), March 7, 2008, Barcelona, Spain.
- 16. 6th Australasian Symposium on Grid Computing and e-Research (AusGrid 2008), Jan. 24, 2008, Wollongong, Australia.

Community Information Sources

- Maintained a Grid Computing Information Centre at: <u>http://www.gridcomputing.com</u>, whose newsletter mailing list has over 2210 members. This website is often ranked as #1 source for grid computing by Google search engine.
- Maintained a Cluster Computing Information Centre at: <u>http://www.buyya.com/cluster</u>

7. International Visiting Researchers

- Dr. Pramod Kumar Konugurthi, Indian Space Research Organisation, Hyderabad, India, Aug 2007-Jan 2008. On DEST Fellowship.
- Professor H. J. Siegel, Colorado State University, USA, June 2-20, 2008.
- Dr. Ivona Brandic, Vienna University of Technology, Austria: June 1 July 31, 2008.
- Xiao Feng Wang, National University of Defense Technology (NUDT), Changsha, China, Nov 2007-Nov-2008. (China Scholarship Council's Fellowship)

8. Selected Projects/Programs

Gridbus: Middleware for Utility-based Grid Computing

Web: http://www.gridbus.org/

An Inaugural Knowledge Transfer Award Winning Project at the University of Melbourne

The flagship project of the Grid Computing and Distributed Systems (GRIDS) Laboratory is the Gridbus Project which covers various research sub-projects that look into the management of distributed resources and scheduling of applications on global Grids. The Gridbus Project is unique in that it explores the practical application of well-known economic theories to solve resource management problems in Grids. In addition to fundamental R&D, the Gridbus Project has also partnered with various scientific, engineering, and business communities in applying Grid technologies to solve various challenging problems in e-Science and e-Business domains. The Gridbus Project has advanced the discipline of Grid computing in the following ways:

- Carried out fundamental research in distributed resource management and application scheduling on global Grids.
- Pioneered the principles of Grid economy as well as techniques and mechanisms that enable the delivery of Grid services as utility-like services.
- Proposed several adaptive scheduling algorithms for deploying applications on global Grids based on users' quality of service (QoS) requirements.
- Co-developed fundamental Grid technologies that enable the creation of scalable Grid environments as well as support the rapid development of Grid-enabled applications.
- Applied Grid technologies to several applications in collaboration with domain scientists, and deployed them both on national and international Grid infrastructure.

The research probes include:

- Service-Oriented Grid Architecture
- Grid Economy and Resource Management.
- Grid Service Broker
- .NET based Enterprise Grid Framework (Aneka)
- Grid Workflows and Scheduling
- Service Level Agreements (SLA)-based Resource Allocation Systems (Libra).
- Grid Simulation Toolkit (GridSim).
- Resource Usage Accounting (GridBank).
- Grid Application Development Environment
- Open SensorWeb Architecture.
- InterGrid for peering and internetworking between islands of Grids
- Application Targets: Drug Discovery (WEHI), Neuroscience (HFI & Osaka Uni), Kidney Modelling, Natural Language Processing, High-Energy Physics, Catchment Hydrology (eWater CRC), and Financial Investment Risk & Portfolio Analysis (Spain).

The software developed as part of the Gridbus Project has been released as open source which enables practitioners around the world to benefit from the products of the Grid research carried out at the University of Melbourne. The Grid software technologies developed by the Gridbus Project such as Gridbus Broker, GridSim, and Alchemi have helped a broad range of people, from research students and established academics to industrial practitioners in institutions and enterprises around the world. Other activities such as training of students on real Grid projects, and tutorials and seminars in conferences around the world have produced benefits both in Australia and around the world. Therefore, by developing, sharing and teaching fundamental Grid technologies, the project has been able to make immense impact on scientific, engineering, and business communities around the world. Recently, the project received a large International Science Linkage (ISL) grant from the Commonwealth DEST to establish strategic research linkages with international projects based in Europe, USA, and Asia.

Aneka: .NET-based Cloud Computing

Staff: Rajkumar Buyya, Xingchen Chu, Chao Jin, Christian Vecchiola Grid Computing and Distributed Systems (GRIDS) Laboratory ARC Discovery Project, DEST International Science Linkage Program **Web:** http://www.manjrasoft.com

ANEKA provides a set of services that make construction and development of Clouds and their applications as easy as possible without sacrificing flexibility, scalability, reliability and extensibility. It is now commercialized through Manjrasoft, a startup company of the University of Melbourne. The key features supported by ANEKA are:

- A configurable and flexible execution platform (container) enabling -
 - pluggable services;
 - security implementations multiple authentication / authorisation mechanisms such as role-based security and Windows domain-based authentication;
 - multiple persistence options including RDBMS, SQL Express, MySQL and flat files;
- SDK (Software Development Kit) supporting multiple programming models including -
 - Object oriented thread model,
 - Task model for legacy applications
 - Map Reduce model for data-intensive applications
 - Custom tools such as Design Explorer for parameter sweep studies
- Easy to use management tool for SLA and QoS negotiation and resource allocation.



Gridbus Broker: A Scheduler for Automatic Deployment of Applications on Global Grids

Web: http://www.gridbus.org/broker

The Gridbus broker is an advanced service-oriented meta-scheduler for compute and data Grids, with support for a wide range of Grid middleware and services. It takes care of many functions that Grid applications require including discovering the right resources for a particular user application, scheduling jobs in order to meet deadlines and handling faults that may occur during execution. In particular, the broker provides capabilities such as resource selection, job scheduling, job management and data access to any application that requires distributed Grid resources for execution. The broker handles communication with the resources running different Grid middleware, job failures, varying resource availability, and different user objectives such as meeting a deadline for execution or limiting execution within a certain budget. Hence, it makes Grids more appealing and approachable to user communities who want to access the increased computing power but are not familiar with using distributed systems.



The Grid Resource Broker has been used in a variety of scenarios and application domains by different scientific and business organizations. These include executing data mining programs on grid resources (European Union Data Mining Grid led by DaimlerChrysler and University of Ljubljana); integrating different kidney models and visualizing them (Melbourne Medical School and Université d'Evry, France); business applications (Infosys and HCL) and exploring semantics-based composition and trust in Grids (Anna University as part of the Indian National Grid), to name a few. The broker is hosted as an open-source project on Sourceforge.net, a website where any interested developer can join a project they are interested in, download the source code and contribute to it. This ensures that the latest source code from the Project is directly available to the public and partners/users are able to contribute towards further enhancement of our technologies.

QoS-Oriented Grid Workflow Engine

Web: http://www.gridbus.org/workflow

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 QoS requirements of e-Research application workflows, this project aims to develop Grid technologies that support (a) QoS-based scheduling of e-Research application workflows on distributed resources, (b) mechanisms for formulating, negotiating and establishing service level agreements (SLA) with resource providers and (c) SLA-based allocation and management of resources. Specifically, the project aims to:

- Define an architectural framework and principles for the development of QoS-based workflow management and SLA-based resource allocation systems,
- Develop QoS-based algorithms for scheduling e-Research workflow applications,
- Develop SLA-based negotiation protocols and resource allocation algorithms,
- Implement a prototype system by incorporating the algorithms and policies developed above, and
- Develop real world demonstrators in various scientific domains such as life sciences.

Key Reference: [1] 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, ISSN: 1058-9244, IOS Press, Amsterdam, The Netherlands, Nov. 2006.



Fig. 1: Architecture of QoS-based workflow management and resource allocation system.

GridSim: A Toolkit for Modelling and Simulating Grid Computing Environments

Web: http://www.gridbus.org/gridsim

GridSim is a software platform that enables users to model and simulate the characteristics of Grid resources and networks with different configurations. GridSim is of great value to both students and experienced researchers who want to study Grids, or test new algorithms and strategies in a controlled environment. By using GridSim, they are able to perform repeatable experiments and studies that are not possible in a real dynamic Grid environment. Key features of GridSim are:

- Various allocation or scheduling policies can be made and integrated into GridSim easily, by extending them from one of the classes.
- Has the infrastructure or framework to support advance reservation, auction and Data Grid functionalities of a Grid system.
- Has the ability that reads workload traces taken from supercomputers for simulating a realistic Grid environment. This functionality is useful for testing a resource scheduling problem.
- Incorporates a background network traffic functionality based on a probabilistic distribution. This is useful for simulating over a public network where the network is congested.

Research students in the GRIDS Laboratory are themselves heavy users of GridSim and extend it whenever necessary for their own research needs. In the last 5 years, GridSim has been continuously extended in this manner to include many new capabilities and has also received contributions from external collaborators. In particular, National University of Singapore has contributed a QoS-based network module, and The University of Ljubljana has contributed a DataGrid module. Academic and industrial users of GridSim include: IBM, Unisys, HP, University of Southern California, France Telecom, Indian Institute of Technology, and Sweden's Ume°a University. The table below lists some of the more prominent users of GridSim.

Application Domain	Organisation
Scientific Workflows	The University of Southern California, USA
Business Grids	IBM Research Lab
Grid Resource and Virtual Organisation	Umeå University, Sweden
Network modelling	National University of Singapore
Grid Security Studies	France Telecom
Scheduling Studies	University of Malay
Grid economics	Technical University of Catalunya, Spain
Grid Market Studies	Indian Institute of Technology
Semantic Grid Studies	Monash University
Utility-based Resource Management	The University of Manchester, UK
DataGrid Simulation	The University of Ljubljana, Slovenia.
Data Centre Modelling	Unisys, USA
Multi-Criteria Grid Scheduling	Poznan Supercomputing Center, Poland
Hierarchical Scheduling	Universidad Complutense de Madrid, Spain
Grid Network Buffer	The University of Castilla La Mancha, Spain

Table 1: Various users of GridSim and their targeted application domain for simulation.

InterGrid: Peering Architecture and Policies for Internetworking Disparate Grids

Web: http://www.gridbus.org/intergrid

Grid computing enables the creation of Cyberinfrastructure for e-Research applications. Several nations around the world including Australia have developed their own national Grids based on the notion of virtual organisations. These dispersed Grid initiatives have resulted in islands of Grids without any support for peering arrangements between them. This limitation will impede realisation of full potential of the Grid computing paradigm. This InterGrid project aims to revolutionise Grid computing by investigating and developing (a) architectural principles for interlinking Grids, (b) mechanisms for resource provisioning and allocation within and across Grids and (c) peering policies and algorithms for inter-Grid resource management.

An Application Driver: Scientists from U.S.A, France, New Zealand and Australia have developed mathematical models of kidney functions and have been sharing these models via Grids. It is easy to extrapolate this to sharing of different models related to other organs that are developed within Grids dedicated to them. In order to build a complete model of the human physiology (e.g. IUPS Physiome Project) one needs the capability that supports composition of models from different Grids. These models may be discovered through distributed information services enabled by peering of such Grids, which are controlled by the respective communities. Realising this scenario requires participants to allocate resources from different islands of Grids in a seamless manner, and permit peering among Grids, which are under different administrative policies and political boundaries – as indicated in Figure 1.

Key Reference: Marcos Dias de Assunção, Rajkumar Buyya and Srikumar Venugopal, <u>InterGrid:</u> <u>A Case for Internetworking Islands of Grids</u>, Concurrency and Computation: Practice and Experience, Online ISSN: 1532-0634; Print ISSN: 1532-0626, Wiley Press, New York, USA, 2007.



Fig. 1: InterGrid-based Integrated Human Physiome Environment.

iCDN: Internetworking of Content Delivery Networks

Web: http://www.gridbus.org/cdn

Content Delivery Networks (CDNs) replicate content over several mirrored Web servers, strategically placed at various locations to deal with flash crowds and to enhance response time. The requirements for providing high quality service through global coverage might be an obstacle for new providers, as well as affecting commercial viability of the existing ones. Although many CDN providers exist, they do not cooperate in delivering content to end users in a scalable manner. This project aims to provide a means for distinct CDNs to coordinate and cooperate with other CDNs, by investigating and developing (a) an architecture for an open and decentralized system to support effective internetworking between CDNs achieved through peering arrangement; (b) protocols for service delivery in a cooperative environment of CDNs; (c) economic models for an effective content replication policy; and (d) policies for autonomic management of service level through resource negotiation in an on-demand basis.

An Application Driver: An internetworking of CDNs is formed by a set of autonomous CDNs, which cooperate through a mechanism that provides facilities and infrastructure for cooperation in order to virtualize multiple providers. Architecture of a system to assist the creation of internetworking between CDNs is shown in Figure 1. Such a constellation permits flexible resource sharing and dynamic collaboration between autonomous CDNs in the form of Virtual Organizations (VOs). The 'resource sharing' approach in the internetworked CDNs model endeavours to balance a CDN's service requirements against the high costs of deploying customer-dedicated and therefore over-provisioned resources. Proper management and cooperation will enable a CDN to avoid violating SLAs even when the service demands could not have been predicted ahead of time.

Key Reference:



[1] Buyya, R., Pathan, A. M. K., Broberg, J., and Tari, Z. A Case for Peering of Content Delivery Networks. *IEEE Distributed Systems Online*, 7(10), USA, Oct. 2006.

Fig. 1: Architecture of a system to assist the creation of internetworked CDNs

9. Software Releases

1. Grid Service Broker (v.3.1) Software

The Gridbus Project at the University of Melbourne (Australia) released a new version of the Grid Service Broker. The broker provides capabilities such as resource selection, job scheduling, job management and data access to any application that requires distributed grid resources for execution. The broker handles communication with the resources running different grid middleware, job failures, varying resource availability and different user objectives, such as meeting a deadline for execution or limiting execution within a certain budget.

With the current release, version 3.1, a new organizational structure is provided for the broker, wherein the core is separated from additional capabilities provided as plug-ins that can be selected according to usage requirements. A new Ant build file has been provided to enable selection of plug-ins and the automatic configuration of the broker thereof. Also available is a new external plug-in that uses the capabilities of the Gridbus broker to schedule grid workflows.

New features include:

- Plug-in structure for middleware and programming models.
- Ant build file for automatic downloading and configuration of broker installation.
- Workflow engine plug-in.
- Thread programming model plug-in (similar to Alchemi Grid Threads).

Gridbus in e-Science Enablements

The Gridbus Broker has been used in Grid enabling several e-Science and e-Business applications. The most recent usages include:

- European Union-funded Data Mining Grid Project, which developed set of grid-based data-mining tools and used Gridbus Broker in managing execution of data mining computations on global grids: www.datamininggrid.org/.
- KidneyGrid partners, including Melbourne Medical School and Université d'Evry (France), created a grid portal that integrated distributed kidney models.
- As part of the Australian National Grid (APACGrid), a portal for docking of molecules from CDB with protein target with the aim of discovery potential drug candidates: http://grid.apac.edu.au/OurUsers/MolecularDocking.

Base Technologies

The Gridbus Broker v3.1 supports/uses the following middleware: Globus 2.4.x, Globus 4.0.2, Alchemi 1.0.6, Condor 6.8.4, OpenPBS 2.3, SGE, NWS 2.8, SRB(Storage Resource Broker) 3.x The Gridbus Broker v3.1 supports/uses the following programming model:

- Task/Job model.
- Gridbus Workflow.
- Grid Threading Programming Model.

The Gridbus Broker v3.1 can utilize a resource via SSH for submitting and executing grid jobs on: OpenPBS 2.3, Condor 6.8.4, SGE, Fork (on Unix-like OSes). The broker source code, binaries, documentation and manual can be downloaded from www.gridbus.org/broker/.

2. GridSim Toolkit 4.1

The Gridbus Project at The University of Melbourne, Australia has released the next-version of Grid simulation software, the GridSim Toolkit 4.1. The new version of GridSim adds a new functionality that supports resource failures and failure detection of Grid resources.

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. In addition, we have decided to use SourceForge (http://sourceforge.net/projects/gridsim) for hosting our future releases and developments. This allows us to share and and to collaborate further on new functionalities. Therefore, contributions to the GridSim Toolkit are greatly appreciated.

The early version of our GridSim toolkit has been used/dowloaded by several academic and commercial organizations around the world including: University of Southern California (USA), California Institute of Technology (USA), Argonne National Labs (USA), University of Manchester (UK), CERN, Universidad de Santiago de Compostela (Spain), Indian Institute of Technology, Tsinghua University (China), Sun Microsystems, IBM Research, Unisys, HP, Northrop Grumman Information Technology, British Telecom and EMC Corp.

The GridSim software has been used for modeling and simulating many interesting systems and ideas. For example, IBM Research uses our DataGrid package to simulate a grid meta-scheduler that tightly integrates the compute and data transfer times of each job. Another example is Universidad de Santiago de Compostela's extension of GridSim to optimize execution of parallel applications on a Grid. Our own uses include simulating economic Grid scheduler in a competitive economy model, economic based cluster scheduler and cooperative Grid federation.

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

- Rajkumar Buyya, GRIDS Lab @ The University of Melbourne.
- Manzur Murshed, GSCIT @ Monash University, Australia.
- Anthony Sulistio, GRIDS Lab @ The University of Melbourne.
- Gokul Poduval and Chen-Khong Tham, National University of Singapore.
- Marcos Dias de Assuncao, GRIDS Lab @ The University of Melbourne.
- Uros Cibej and Borut Robic, The University of Ljubljana, Slovenia.
- Agustin Caminero, Universidad de Castilla La Mancha (UCLM), Spain.

To download the GridSim software, please visit the Gridbus Project web site at http://www.gridbus.org/gridsim/

10. Continuing Members Profile and Activities

Member Self Profile: Alexandre di Costanzo

In May 2008, I entered into my new role as a Research Fellow in the GRIDS Lab appointed to work on the ARC Discovery project "InterGrid: Peering Architecture and policies for Internetworking Disparate Grids". This project aims to provide a software system that allows the creation of execution environments for various applications on top of the physical infrastructure provided by the participating Grids. The allocation of resources from multiple Grids to fulfill the requirements of the execution environments is enabled by peering arrangements established between gateways.



I mainly worked on the implementation of a prototype to run real experiments, with the precious help of Marcos. We also worked together on cloudy policies for evaluating the cost-benefit of using cloud computing to extend the capacity of clusters (work publish at HPDC 2009).

In 2009, I am working on a new policy based on Peer-to-Peer to negotiate the use of resources between gateways. Of course, I am still working on Cloud Computing and Virtualization.

Before joining the GRIDS lab, I was member of the OASIS research group at INRIA Sophia Antipolis, France. OASIS develops the ProActive Parallel Suite a Java library for distributed computing.

Member Self Profile: Xingchen Chu

It was my third year working as a software engineer and researcher in the GRIDS Lab. The primary project I was working on is to enhance the Aneka software (a multi-model enterprise desktop platform) and bring it into a commercial product that not only becomes the backbone technology of conducting research for the researchers in our lab, but also a competitive product in the commercial market.

Aneka was promised to provide SLA to the users to provide resource guarantee for their applications. Therefore, one of the goals in 2008 was to create a reservation system for SLA negotiation between Aneka and



consumers. We have successfully prototyped this through the creation of a negotiation system between the Gridbus broker and Aneka. The outcome of this effort appeared as a paper in IWQoS 2008 conference. Based on the enhancement of the core technology in Aneka, we had successfully applied an international patent (pending) for Aneka and commercialized the software into a spin-off company called Manjrasoft, which the major product of the company is Aneka. Moreover, I had managed to build a customized application for utilizing Aneka to accelerate image rendering process for Maya 2008, and it helped the company get the first customer from China.

Other than this, I have worked with our international partners in Spain to provide an implementation of Grid-superscalar programming model on top of the Gridbus workflow system. The outcome of the work enhanced the Gridbus workflow system to support Grid-superscalar model, and a paper was published in the HPC Asia conference.

The last excellent outcome of 2008 was worked on a project for writing a textbook for Java programming language. We had successfully finished the first draft late in 2008.

In 2009, I will continue my work on Aneka with focus on providing seamless integration with Cloud providers such as EC2, and provide Aneka as a common platform for people who want to program and utilize the power of Cloud computing.

Member Self Profile: Christian Vecchiola

In 2008 I joined the GRIDS Lab as a Postdoctoral Research Fellow working on Distributed Evolutionary Computation and Global Grids. I completed my Ph.D. at the University of Genova, Italy with a thesis on *"Providing Support for Evolvable System: An Agent-based Approach"*. Since I joined the GRIDS Lab I focused my interest on two main aspects: distributed implementation of network based genetic algorithms and reliable, scalable, and configurable middleware for distributed systems.

Genetic algorithms are compute intensive and time consuming optimization algorithms that can be applied to different real life scenarios such as airfoil dynamic design, protein structure prediction, and virtually any problem that can be characterized by a single or multi-objective function that needs to be optimized. By using a



distributed infrastructure to execute these algorithms, it is possible not only to reduce the execution time and provide optimal result more promptly but also to investigate different solution models by using different distribution strategies and distributed programming models. As a result of my research in this field I have provided a distributed implementation of the Evolutionary Multi-Objective (EMO) algorithm that was previously designed and implemented under the supervision of Dr. Michael Kirley at the University of Melbourne. EMO is a variant of the most popular NSGA-II algorithm that uses network information, link between individuals, to drive the evolutionary process of the algorithm. The use of network information has been proven to be a successful contribution to the discovery of better solutions, with the distributed implementation of EMO a stronger emphasis is put on the use of the network information between individuals to differentiate the evolution of different nodes. Together with the use of statistical indicators, it is possible to identify which between the different network topologies has produced better result and use this information to improve the evolution process.

Distributed middleware can help the execution of genetic algorithms. Part of my activities during my research fellowship has been focused on extending and improving the Aneka framework, which is software framework for developing distributed applications on Enterprise Grids and Clouds. Aneka provides different programming models that can be used to the express a distributed application. A programming model is a collection of components (scheduling services, execution services, and client APIs) that coordinated together provide the ability to represent and execute a distributed application by using e specific set of abstractions. Aneka, currently supports three different programming models: distributed threads; bag of independent tasks; and MapReduce. In this year I have provided a distributed infrastructure for EMO by using the independent bag of tasks model and the MapReduce model.

In 2009, I will continue exploring the different distribution models for population based evolutionary algorithm and I will approach a workflow based implementation of EMO that will fully make uses of topology information between individuals and statistical indicators to control the evolutionary process. For what concern the development and the advancement in Aneka I will provide focus on the Service Level Agreement and Quality of Service features of the system with a specific emphasis for workflow execution.

C. Vecchiola, M. Kirley, and R. Buyya, *Multiobjective Problem Solving with Offspring on Enterprise Clouds*, Proceedings of the 4th HPC ASIA 2009 International Conference, March 1-5, 2009, Kaohsiung, Taiwan.

C. Jin, C. Vecchiola, and R. Buyya, *MRPGA: An Extension of MapReduce for Parallelizing Genetic Algorithms*, Proceedings of the 4th IEEE International Conference on e-Science, (e-Science 2008, IEEE CS Press, Los Alamitos, CA, USA), December 10-12, 2008,

Visiting Member Self Profile: Rodrigo N. Calheiros

I am Rodrigo N. Calheiros. I'm from Porto Alegre, Rio Grande do Sul, Brazil. I am a PhD in the Pontifical Catholic University of Rio Grande do Sul (PUCRS), where I'm current in the third year of my course. Since August 2008, I've been worked in the GRIDS lab as a visiting student, where I'm staying for one year. My visit is sponsored by the Brazilian government, through the CAPES PDEE scholarship program (aka "sandwich" PhD). My Brazilian supervisor is Professor César A. F. De Rose.

Before starting my PhD, I got a Degree in Computer Engineering by Federal University of Rio Grande (FURG) and a MSc. Degree in Computer Science by PUCRS (also supervised by Prof. De Rose). The research topic in my masters thesis was resource scheduling in Grid



Computing¹, specially for the case of allocating idle cycles of clusters for executing grid applications. My masters was funded by Hewllet-Packard Brazil R&D.

My PhD search is on virtualization technology and its application in distributed systems emulation^{2,3}, and it was also a partnership with HP Brazil R&D. Since I arrived in Melbourne, I've been working in the CloudSim project, originally developed as a tool to support simulation scenarios required by my thesis topic. Since then, it has grown to become a tool to support several researches in the emerging Cloud Computing area. We are working to increase CloudSim's users base to make this tool as successful as GridSim is. I'll be working on it until July 2009, when I will return to Brazil to conclude my PhD.

My current research interest areas include Resource Management in Clouds and Grids, Simulation, Emulation, and Virtualization.

1. R. N. Calheiros, T. Ferreto, and C. D. Rose. Scheduling anf management of virtual resources in grid sites: the Site Resource Scheduler. Parallel Processing Letters, 19(3):3-18, 2009.

2. R. N. Calheiros, M. Storch, E. Alexandre, C. A. F. De Rose, and M. Breda. *Applying virtualization and system man-agement in a cluster to implement an automated emulation testbed for grid applications*. In 20th International Symposium on Computer Architecture and High Performance Computing SBAC-PAD, 2008.

3. R. N. Calheiros, E. Alexandre, A. B. do Carmo, C. A. F. De Rose, and R. Buyya. *Towards self-managed adaptive emulation of grid environments*. In IEEE Symposium on Computers and Communications (ISCC), 2009.

Member Self Profile: Marco A. S. Netto

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 third 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. My thesis is on (re)scheduling of applications that require resource co-allocation.

In 2008, I worked with the scheduling of Bag-of-Tasks applications for multi-site environments. I considered an environment in which resource providers cannot disclose private information such as local load and total resource capabilities. Providers generate resource offers to a metascheduler, which is responsible for composing the offers in order to meet user deadlines.

I have also worked in a survey on resource co-allocation for Grid environments. The survey covers four main research areas on resource co-allocation: distributed transactions, fault tolerance, inter-site network overhead, and schedule optimization. The survey also classifies some of the current software systems that support resource co-allocation.

I am currently working on the deployment of parallel applications in multi-site environments. The main goal of this phase is to investigate practical constraints to use the Flexible Resource Co-allocation model that I introduced in 2007.

For the list of publications and details about my past and current work, please visit my webpage: http://www.csse.unimelb.edu.au/~netto

Member Self Profile: Mukaddim Pathan

I am a Final year PhD student in the **GRIDS** Laboratory of the University of Melbourne, Australia. I'm working in the project, entitled "Coordinated Management and Peering of Content Delivery Networks". This project aims to provide a means for distinct CDNs to coordinate and cooperate with other CDNs, by investigating and developing (a) an architecture for an open and decentralized system to support effective internetworking between CDNs achieved through peering arrangement; (b) protocols for service delivery in a cooperative environment of CDNs; (c) economic models for an effective content replication policy; and (d) policies for autonomic management of service level through resource negotiation in an on-demand basis.



In 2008, I published research papers in renowned international conferences such as Cooperative Information Systems (CoopIS)

and International Conference on Networks (ICON). In order to attend to these conferences I travelled to Mexico and India. Along with the conference participation, I have visited Tech De Monterrey and Universidad Autonoma De Neuvo Leon in Monterrey, Mexico. One of my papers has also been accepted in the Multiagent and Grid Systems (MAGS) journal. My achievements in 2008 also include receiving the Dreamlarge Knowledge Transfer Student Grant for the project "Knowledge Transfer of Next-Generation Grid Technologies to Empower Emerging Economies". This project shares GRIDS Lab and Gridbus research and innovations with leading institutions of South-East Asian countries, such as India and Bangladesh, with the following objectives:

- Dissemination of accumulated knowledge such as a published book, handouts and brochures as part of the KT Kit to the partners and students.
- Showcasing individual student research project through the Web, online streaming and high quality KT Videos (Please check the Knowledge Transfer Video in YouTube).
- Commercializing innovations of students through Manjrasoft Pty. Ltd., a company of the University.
- Global elevation of the 'Melbourne Model' philosophy to attract potential overseas students, while simultaneously enhancing Australia's credibility as a KT expert.

Me, along with my supervisor, A/Prof. Rajkumar Buyya visited many universities and technical Institutions, such as Anna University, BUET, KUET, Dhaka University, and IUT, in India and Bangladesh to carry out the project activities. I was also involved as a co-chair in the organization of the UPGRADE-CN'08 and IDCS'08 workshops and served as a PC member of several international conferences. I also worked as a reviewer of a few renowned international conferences, journals and magazines such as IEEE Transactions on Circuits and Systems for Video Technology (TCSVT), Computer Networks, Computer Communications, International Journal of Management Science, and IEEE Software.

Currently, I am working towards conducting large-scale experiments on MetaCDN (www.metacdn.org) testbed, which conceptualizes the vision of peering CDNs. I am looking forward to submitting my PhD thesis in the near future.

Member Self Profile: Mustafizur Rahman

I am a third year PhD student under the supervision of Dr. Rajkumar Buyya in Grid Computing and Distributed Systems (GRIDS) Laboratory of The University of Melbourne. My research interest includes scheduling and optimization of scientific workflow applications as well as autonomic management of Grid workflow systems. The main focus of my PhD research is to develop mechanisms for scheduling and autonomic management of scientific workflow applications in global Grids.

In the first half of 2008, I worked on development of Gridbus Workflow Editor and its integration with Gridbus Workflow Engine as part of preparing the demo for SCALE 2008.

In May 2008, I attended 8th IEEE International Symposium on

Cluster Computing and the Grid (CCGRID 2008), organized by INRIA, Lyon, France. In the conference, I presented my paper and participated in 1st IEEE International Scalable Computing Challenge (SCALE 2008). After the conference, I visited Vrije University and University of Amsterdam for one week.

In the second half of 2008, I worked on developing a decentralized and cooperative workflow scheduling technique2. The developed approach utilizes a Peer-to-Peer (P2P) coordination space to coordinate the application schedules among the Grid wide distributed workflow brokers. With the implementation of this approach, not only the performance bottlenecks are likely to be eliminated but also efficient scheduling with enhanced scalability will be achieved.

I extended this work and developed a dependable workflow scheduling algorithm to counter the effect of unreliability and temporal characteristics of computing resources in large scale, decentralized Grid overlays. The proposed algorithm can dynamically adapt to changing resource conditions and offer significant performance gains as compared to traditional approaches in the event of unsuccessful job execution or resource failure.

Besides doing my research, in 2008, I was also involved in professional development activities. I worked as Web and Publicity Chair to organize 1st International Workshop on Data Mining and Artificial Intelligence (DMAI 2008) in December at Khulna, Bangladesh. During the year, I also received several Scholarships and Grants that include Melbourne Abroad Travelling Scholarship, IEEE TCSC Student Travel Grant and Dreamlarge: Knowledge Transfer Student Grant.



¹ Mustafizur Rahman, Rajiv Ranjan, and Rajkumar Buyya, "Dependable Workflow Scheduling in Global Grids", Submitted to 10th IEEE/ACM International Conference on Grid Computing (Grid 2009), Canada, October 2009.

² Mustafizur Rahman, Rajiv Ranjan, and Rajkumar Buyya, "Cooperative and Decentralized Workflow Scheduling in Global Grids", Under Review in *The International Journal of Grid Computing: Theory, Methods, and Applications (FGCS)*, Elsevier Press, Nederland.

³ Suraj Pandey, William Voorsluys, Mustafizur Rahman, Rajkumar Buyya, James Dobson, and Kenneth Chiu, "A Grid Workflow Environment for Brain Imaging Analysis on Distributed Systems", To Appear in *Concurrency and Computation: Practice and Experience*, Wiley Press, USA, 2009.

⁴ Suraj Pandey, William Voorsluys, Mustafizur Rahman, Rajkumar Buyya, James Dobson, and Kenneth Chiu, Brain Image Registration Analysis Workflow for fMRI study in Global Grids, In Proceedings of *23rd IEEE International Conference on Advanced Information Networking and Application (AINA 2009)*, Bradford, UK, May 2009.

Member Self Profile: Saurabh Kumar Garg

I am a PhD student under the supervision of Dr. Rajkumar Buyya in Grid Computing and Distributed Systems (GRIDS) Laboratory of The University of Melbourne. I started my candidature in August 2007. I completed my 5-year Integrated Master of Technology in Mathematics and Computing from the Indian Institute of Technology (IIT) Delhi, India, in 2006. After completing my post graduate degree, I joined the IBM Indian Research Laboratory Delhi, where I worked in the area of High Performance Computing. I designed and optimized the FFT and Random Access



benchmarks for Blue Gene/L, which is the fastest supercomputer from IBM. Here in Melbourne University, I has been awarded with various scholarships such as Nicta-Topup Scholarship, MIFRS, and MIRS for my PhD candidature.

After joining GRIDS Laboratory, I studied various research works in the field of Grid computing. Thus, I studied utility computing, market principles in grid computing, SLA based resource allocation, workflow, data grids etc. This study not only gave me a strong foundation in the area but also gave me insight for some of the open problems. I developed my expertise in simulation modelling particularly in Grid Simulation Toolkits such as GridSim and Gridbus Broker. I also developed a simple design of meta-broker while working on Gridbus Broker.

My current research interest is in developing various market based policies for meta-broker which will map multiple resources to multiple Grid consumers to achieve the balance in demand and supply, improve the throughput while maximizing the utilities of Grid consumers and providers. I also examined the problem of contention at a resource by introducing a third party meta-broker which allocates resources to users in a coordinated manner.

I have proposed various meta-scheduling policies^{1, 2, 3} to solve this problem. These works received recognition both at national and International level and thus received three best paper awards. I am also awarded with the DreamLarge Knowledge Transfer Project Grant with my other colleagues for the project, entitled, "Knowledge Transfer of Next-Generation Grid Technologies to Empower Emerging Economies"⁴. These grants are awarded to appreciate and encourage the qualities of leadership, project management, and interdisciplinary collaboration.

¹Garg S. K., Konugurthi P. K., and Buyya R., "A Linear Programming Driven Genetic Algorithm for Meta-Scheduling on Utility Grids", The 16th International Conference on Advanced Computing and Communication, December 2008 (Received "Best Paper" Award).

²Garg S. K., Venugopal S., and Buyya R., "A Double Auction-based Meta-Scheduler for Multi-Cluster and Global Grids", The 14th IEEE International Conference on Parallel and Distributed Systems, December 2008.

³Garg S. K., Buyya R., and Siegel H. J.,

"http://www.engr.colostate.edu/~hj/conferences/296.pdfScheduling ParallelApplications on Utility Grids: Time and Cost Trade-off Management," Australasian Computer Science Conference (ACSC2009), cosponsors: Australian Computer Society and New Zealand Computer Society, Wellington, New Zealand, Jan. 2009. (Received "Best Paper" and "Best Student Paper" Award).

⁴http://www.gridbus.org/cdn/ktp/

Member Self Profile: Suraj Pandey

I received my Master's degree from Inha University, South Korea in February 2007. After enrolling as a Ph.D. student and doing course work in KAIST, South Korea, for 6 months, I realized that my interests lie in Distributed Computing rather than core databases. So, I joined GRIDS Lab as a Masters by Research student (leading to a Ph.D. degree) in June 2007 under IPRS and MIRS scholarships. Prof. Rajkumar Buyya is my supervisor.

In 2007, I started my research degree in **Scheduling of Workflows in Data-Intensive Environments**. The year 2008 has been very productive for me. The engineering work I have done so far has resulted in 1 journal publication [a] and 1 conference publication [b]. We also demoed the system at the 4th IEEE International Conference on e-Science (e-Science 2008), Indianapolis, IN, USA, 2008. Our proposal was published as a demo-paper in the proceedings [c].

I am currently working on the following topics:

- 1) Multi-source-parallel-data transfer techniques for dataintensive workflow applications
- 2) Gridbus Workflow Engine using Amazon EC2+S3 that will be demoed at the SCALE 2009, Shanghai, China.



The list of my publications from PhD research (only 2008) are listed below:

- a) Suraj Pandey, William Voorsluys, Mustafizur Rahman, Rajkumar Buyya, James Dobson, Kenneth Chiu. A Grid Workflow Environment for Brain Imaging Analysis on Distributed Systems. In Concurrency and Computation: Practice and Experience. (In Press).
- b) Suraj Pandey, William Voorsluys, Mustafizur Rahman, Rajkumar Buyya, James Dobson, Kenneth Chiu. Brain Image Registration Analysis Workflow for fMRI Studies on Global Grids. In Proceedings of the 23rd IEEE International Conference on Advanced Information Networking and Applications (AINA-09), Bradford, UK, May 2009.
- c) Suraj Pandey, Chao Jin, William Voorsluys, Mustafizur Rahman, and Rajkumar Buyya. Gridbus Workflow Management System on Clouds and Global Grids. In Proceedings of the Fourth IEEE International Conference on eScience (eScience 2008), Indianapolis, USA, December 2008.

My presentations and demonstrations are listed below:

- a) 4th IEEE International Conference on e-Science (e-Science 2008), Indianapolis, IN, USA, 2008. [Thanks to Christian Vecchiola for demonstrating on our behalf]
- b) First IEEE International Scalable Computing Challenge (SCALE 2008) in conjunction with the 8th IEEE International Symposium on Cluster Computing and the Grid (CCGrid 2008), Lyon - France / May 19-22, 2008. [Presentation + Demonstration]

Member Self Profile: William Voorsluys

I joined GRIDs Lab in February 2008, when I started my PhD studies in the University of Melbourne.

In the past few years, before coming to Melbourne, I've been involved with aspects of grid and cloud computing, virtualization technologies and load balancing in distributed systems. This interest started back in the year 2000 during my undergraduate studies, when I developed load-balancing algorithms for heterogeneous clusters. Later, in my master's research in the University of Sao Paulo, I've studied memoryrelated metrics that allow a precise evaluation of a system's memoryusage, with the objective of aiding cluster load balancing policies to make better decisions.



From 2005 to 2008 I have worked as a researcher in the OurGrid project, a Brazilian grid computing initiative, which is dedicated to research and development of a peer-to-peer grid computing solution.

My PhD research aims at creating a provisioning and allocation mechanism for virtualised data centres. A key feature of my research is the concept of workload mobility. I'm leveraging live migration of virtual machines to achieve load balancing and fault tolerance capabilities. More specifically, my research involves devising a mechanism that uses detailed information about resource utilization in each virtual machine to intelligently consolidate and redistribute the workload in a datacenter.

Apart for diving into my PhD research, my achievements in 2008 included a participation in the Google Summer of Code 2008, when I collaborated with the Globus Alliance. I have also contributed to the Gridbus Workflow project by developing a Web portal, which was successfully demoed in the SCALE competition during CCGRID'08 in Lyon, France.

I was also pleased to be awarded, along with colleagues, the Dreamlarge Knowledge Transfer Award for the project "Knowledge Transfer of Next-Generation Grid Technologies to Empower Emerging Economies" in October 2008.

11. Moments with Visitors, Colleagues and International Hosts



With Prof. Ian Foster (Globus guru) during visit to Argonne National Lab, Chicago (April)



Visit to Ottawa, Canada for presenting a Keynote at the 41st Annual Simulation Symposium (April)



Receiving "Chris Wallace Outstanding Researcher Award 2008" from Jenny Edwards, President of the CORE (Computing Research and Education Association of Australasia) – Jan.



Visit to house of Ampere (father of electrodynamics) with Laurent Lefevre (May)



With Prof. Thomas Fahringer during visit to the University of Innsbruck (Aug)



Receiving "Distinguished Service Award" from the IEEE Computer Society presented at CCGrid 2008 Conference, Lyon, France (May).



GRIDS Lab's young researchers receiving Knowledge Transfer Award from DVC (Research), the University of Melbourne.



With Prof. Thomas Fahringer during visit to the University of Innsbruck (Aug) – on sabbatical.



During visit to Vienna University of Technology, Austria: Dr. Ivona Brandic and Prof.Schahram Dustdarm on the right. (Aug.)



Manjrasoft (commercial arm of GRIDS Lab): Signing Share Holder Agreements with - Ivan Mellado (Melbourne Ventures) (Vice-Principal of Commercialization).



Cloud Computing Workshop at University of Karlsruhe, Germany - Dec. 10, 2008



IBM Seminar/Visit: with Ravi Kothari (IBM), Ravin (DCE), Mukesh Mahania (IBM), Mohan Ram (ERNET Executive Director) - Dec. 13.



Present a book to Bangladesh University of Science and Technology, Dhaka after Knowledge Transfer Seminar (Dec.)