Cloud Computing and Distributed Systems Laboratory
and the Cloudbus Project

www.cloudbus.org

Annual Report - 2018

School of Computing and Information Systems
Melbourne School of Engineering
The University of Melbourne, Australia
1. Director’s Message

I am pleased to report on the key activities and outcomes of Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, Australia during the academic year 2018, which has been another extraordinary year in terms of research quality and international recognition of its members. The Lab has consolidated its position as one of the world-leading innovators in developing innovative solutions for Cloud Computing.

The highlights of research activities and outcomes in 2018 are:

- The Lab successfully hosted two ARC research projects (Discovery and Linkage Projects) along with two industry-funded projects.
- Members of the CLOUDS Lab have authored 62 publications, which include 43 journal papers and 15 conference papers.
- The Lab’s flagship Cloudbus Project has released various new modules for Aneka, CloudSim, iFogSim, and Fogbus. The iFogSim building on CloudSim is emerging as a de-facto Toolkit for modelling and simulation of Fog and Edge computing environments. It has been used by several researchers in academia and industries around the world.
- Members have presented over 26 invited talks that include 6 keynotes delivered at international conferences/seminars held in Australia, India, Indonesia, Mauritius, China, Italy, and France.
- The Lab successfully hosted research activities of over 25 scholars, which include 16 PhD students and 4 Research Fellows.
- “2018 Web of Science Highly Cited Researcher” recognition from Thomson Reuters for a team member!
- In 2018 alone, our papers have attracted over 10280 citations (ref: Google Scholar) and we hope this trend will continue!
- The Lab housed several (short and long term) international visitors (academic and PhD students) from India, China, Germany, Estonia, Slovenia, and UK.
- Our Lab’s spin-off company, Manjrasoft has been recognised as one of the Top 20 Most Trusted Cloud Solution Providers by the Insight Success Magazine.
- Members of the Lab have led community efforts such as (a) the organisation of conferences (e.g., UCC 2018 and BDC 2018 in Switzerland; ICFEC 2018 in USA) and (b) Co-Editor-In-Chief of Journal of Software: Practice and Experience, which was established ~50 years ago.

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!

Sincerely yours,

[Signature]

Professor Rajkumar Buyya, PhD
Director, Cloud Computing and Distributed Systems (CLOUDS) Laboratory
School of Computing and Information Systems
The University of Melbourne, Australia
Web: www.cloudbus.org
2. The Team

Director:

- Professor Rajkumar Buyya

Research Staff:

- Dr. Adel Toosi
- Dr. Maria Rodriguez
- Dr. Sukhpal Singh Gill
- Dr. Jungmin Jay Son

PhD Students

- Mr. Safiollah Heidari
- Mr. Xunyun Liu
- Mr. Jaydeep Das, Indian Institute of Technology, Kharagpur
- Mr. Caesar Wu
- Mr. Minxian Xu
- Ms. Sara Kardani Moghaddam
- Mr. Muhammad H. Hilman
- Mr. Redowan Mahmud
- Ms. Imairi Eitiveni
- Mr. Muhammed Tawfiqul
- Mr. Carlos Gomez, University of Birmingham, UK
- Ms. Maria Salama, University of Birmingham, UK
- Mr. Anit Khan, Monash University, Australia
- Mr. Shashikant Ilager
- Mr. TianZhang He
- Mr. Mohammad Goudarzi
- Mr. Zhiheng Zhong

Collaborators

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

International Visitors

- Prof. Satish Narayana Srirama, University of Tartu, Estonia: Jan-Feb 2018.
- Prof. Vlado Stankovski, University of Ljubljana, Slovenia, July 1-Sept 30, 2018.
- Prof. Stefan Voß, University of Hamburg, Germany, Aug 1-15, 2018.
- Shreshth Tuli, Indian Institute of Technology Delhi, India, May-July 2018.
3. Competitive Grants Funded Projects and Programs - Active

**Australian Research Council (ARC)**


**Other National Grants**


**Industry and Melbourne University Grants**

4. Publications

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

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</table>

Books/Proceedings Edited


Book Chapters


Journal Editorials


Journal Papers


8. Li Liu, Shuxian Gu, Dongmei Fu, Miao Zhang, and Rajkumar Buyya, A New Multi-objective Evolutionary Algorithm for Inter-Cloud Service Composition, KSII Transactions on Internet and Information Systems (TIIS), Volume 12, Number 1, Pages: 1-20, ISSN: 1976-7277, KSIT Press, Seoul, Korea, January 2018.


Magazine Papers


Conference Papers


58. Sukhpal Singh Gill, Rajesh Chand Arya, Gurpreet Singh Wander, and Rajkumar Buyya,
Fog-Based Smart Healthcare as a Big Data and Cloud Service for Heart Patients Using
IoT, International Conference on Intelligent Data Communication Technologies and
Coimbatore, India, August 7-8, 2018.

59. Carlos Mera-Gómez, Francisco Ramírez, Rami Bahsoon, and Rajkumar Buyya, A Multi-
Agent Elasticity Management Based On Multi-Tenant Debt Exchanges, Proceedings of
the 12th IEEE International Conference on Self-Adaptive and Self-Organizing Systems

60. Bingfeng Liu, Rajkumar Buyya and Adel Nadjaran Toosi, A Fuzzy-based Auto-scaler for
Web Applications in Cloud Computing Environments, Proceedings of the 16th
International Conference on Service Oriented Computing (ICSOC 2018, LNCS, Springer-

61. Adel Nadjaran Toosi and Rajkumar Buyya, Acinonyx: Dynamic Flow Scheduling for
Virtual Machine Migration in SDN-enabled Clouds, Proceedings of the 16th IEEE
International Symposium on Parallel and Distributed Processing with Applications (ISPA

62. Satish Kumar, Rami Bahsoon, Tao Chen, Ke Li, and Rajkumar Buyya, Multi-Tenant
Cloud Service Composition using Evolutionary Optimization, Proceedings of the 23rd
IEEE International Conference on Parallel and Distributed Systems (ICPADS 2018, IEEE
CS Press, USA), Singapore, December 11-13, 2018.

63. Muhammad Hafizuddin Hilman, Maria A. Rodriguez and Rajkumar Buyya, Task
Runtime Prediction in Scientific Workflows Using an Online Incremental Learning
Approach, Proceedings of the 11th IEEE/ACM International Conference on Utility and
Cloud Computing (UCC 2018, IEEE CS Press, USA), Zurich, Switzerland, Dec. 17-20,
2018.
5. Invited Presentations and Outreach

By the Lab Director:

**Keynote Talks at International Conferences**


**National Conferences**


**Seminars - in Cloud Computing area:**

11. Excellence and Impact of Research and Publications, University of Electronic Science and Technology of China (UESTC), Chengdu, China, May 11, 2018.
6. Selected Community Services

By the Lab Director:

IEEE Computer Society

1. Advisory Board, IEEE Technical Committee on Scalable Computing

Software: Practice and Experience (Wiley)

1. Co-Editor in Chief (EiC), 2014-to date.

Journal Editorials


Conference Steering Committee

2. Advisory Committee Member, International Conference on e-Science (e-Science), 2011-to date.
3. Advisory Committee Member, IEEE International Conference on Cluster Computing (ClusterXY), 2011-to date.

Technical Program Committee Memberships


Community Information Sources

- Maintained a Grid Computing Information Centre at: http://www.gridcomputing.com, whose newsletter mailing list has over 2500 members. This website is often ranked amongst top #4 sources for grid computing by Google search engine.
- Maintained a Cluster Computing Information Centre at: http://www.buyya.com/clusterBy

Other Members:

Technical Program Committee Memberships + other Professional Services

* Noted in their profile pages.
**7. Members Profile and Activities**

**Member Self Profile: Adel Nadjaran Toosi**

I worked fulltime with the CLOUDS Laboratory up to May 2018 and then joined the Faculty of Information Technology at Monash University after having worked in CLOUDS Lab for almost 8 years. Before joining Monash, I was a PhD student and then a research fellow at the CLOUDS laboratory. I worked on an ARC Discovery Project and Huawei HIRP Project during my research fellowship.

Last year, I have been working on algorithms and software systems for resource management of software-defined clouds. I published 6 journal articles and three conference papers in 2018. I visited Huawei Shanghai with Jungmin Son (Jay) to deliver our project on SDN to the partner team. I also attended the 2018 ISPA (Melbourne) and ICSOC (Hangzhou, China) conferences.

Below are my conference papers published in 2018:


My CV and full list of my publications can be found in my homepage at [http://adelnadjarantoosi.info/](http://adelnadjarantoosi.info/)
**Member Self Profile: Maria Alejandra Rodríguez**

I joined the CLOUDS Laboratory in 2012 as a student researching scheduling and resource provisioning algorithms for scientific workflows in cloud environments. I completed my PhD in 2016 and I am now working as a research fellow in the lab.

I have researched different topics as part of my current role. I have investigated container orchestration frameworks and different ways in which the use of resources can be optimized in container-based environments.

I have a bachelor’s degree in Computing and Systems Engineering from Los Andes University in Colombia. In 2011 I completed my master’s degree at the University of Melbourne (Master of Engineering in Distributed Computing) with first class honors. I have over three years of industry experience gained while working as a software engineer in Colombia and in Tata Consultancy Services in Bangalore, India.

Some of my papers published in 2018 are:

**Member Self Profile: Sukhpal Singh Gill**

I joined CLOUDS Lab as a Research Fellow in July 2017 and worked on quality of service-based resource management for reliable and sustainable cloud computing and implemented resource management approach using CloudSim.

During 2018, I have been serving as a peer reviewer for many journals including: IEEE Transactions on Parallel and Distributed Computing, Journal of Systems and Software, and IEEE Transactions on Service computing.

I developed an intelligent cloud based and QoS-aware autonomic resource management approach which offers self-configuration of applications and resources, self-healing by handling sudden failures, self-protection against security attacks and self-optimization for maximum resource utilization. I left the Lab in August 2018 to assume a Research Associate position in the Lancaster University, UK.

Below you can find my selected publications related to my research in 2018:


My CV and full list of my publications can be found in my cyber homepage at: [http://ssgill.in/](http://ssgill.in/)
Member Self Profile: Jungmin Son (Jay)

I was a Research Assistant with CLOUDS Laboratory in 2018 who recently moved to Amazon AWS. I received Ph.D. and Master of Information Technology degrees from the University of Melbourne in 2018 and 2013 respectively. Before moving to Melbourne, I worked in Samsung Electronics for four years as a software engineer after completing B.Eng. at Ajou University, South Korea. I received 2018 IEEE TCSC Outstanding Ph.D Dissertation Award that recognizes an outstanding PhD thesis in the field of the scalable computing with combined theory and practice and in-depth technical contributions.

In my current research, main topic includes how to apply SDN to cloud data centres to ensure SLA and energy efficiency. I investigate VM placement policies that aware network resources and network flow control for providing QoS. This work can help to design cloud data centre in energy-efficient fashion, while guaranteeing SLA. Also, I am interested in network flow management using SDN controller which will provide users efficient network performance while cloud providers can still save costs.

For further details about my current status, research interest, open source projects, and recent publication, please visit my personal website:

- https://sites.google.com/site/jungminjayson/
Member Self Profile: Safiollah Heidari

I joined CLOUDS Lab in Jun 2014 at the University of Melbourne as a PhD student under the supervision of Prof. Rajkumar Buyya, Dr. Benjamin Rubinstein and Dr. Rodrigo N. Calheiros.

Previously I have graduated from K. N. Toosi University of Technology, Tehran, Iran, with First Class Honors degree in M.Sc. in Information Technology and I have published a number of papers during my studies. I am also member of Iran’s National Elites Foundation, a prestigious organization for recognize, organize and support Iran's elite national talents.

At CLOUDS Lab, I’m investigating resource provisioning, cost saving, workflow scheduling and network aspects of distributed large-scale graph-processing systems in cloud environments. I developed iGiraph which is a novel Pregel-like graph processing framework for minimizing the monetary costs and computation time of processing on large-scale graph datasets. iGiraph’s paper was appeared in CCGrid 2016 conference in Colombia and also won the Google Ph.D. travel prize at University of Melbourne and the runner-up prize for the best student paper from IEEE Victorian Section.

Later, we introduced “Graph Processing-as-a-Service” (GPaaS) as the next popular cloud service where a full-stack of services is proposed for cloud providers by which GPaaS will play a key role in data storage and analytics within organizations. Our paper on entitled “Quality of Service (QoS)-driven Resource Provisioning for Large-scale Graph Processing in Cloud Computing Environments: Graph Processing-as-a-Service (GPaaS)” that have been accepted in Future Generation Computer Systems (FGCS) journal in 2019 describes this project in detail.

GraphIoT is the latest framework that I created to facilitate processing Internet of Things (IoT) stream graph data in edge and cloud computing environments.

I recently graduated from The University of Melbourne and am working with various entities from academia and industry.
Member Self Profile: Xunyun Liu

I joined the Clouds lab at University of Melbourne in Sept. 2014, under the supervision of Professor Rajkumar Buyya and Dr. Rodrigo N. Calheiros. In 2015, Dr. Benjamin Rubinstein joined my supervisory committee and I was confirmed as a formal PhD candidate.

I graduated from National University of Defense Technology with a master and a bachelor degree on Computer Science and Technology. My research at that time mainly focused on High Performance Computing (HPC) and compiler optimization. In my Master thesis, I designed a fault-tolerant, sender-based message logging protocol over MPI for fast recovery of faulty scientific applications on the world-renowned TH supercomputer.

After the focus of my PhD shifts to the research of Cloud computing, I started developing interested in stream processing of big data on cloud, including resource provisioning, task scheduling, and fault tolerance issues related to real-time processing. Using Apache Storm as the experiment platform, I have been actively working towards the designing and implementation of a SLA-oriented streaming processing platform on cloud.

You are welcome to visit my personal page at https://xunyunliu.github.io/ for the list of my publications and my thoughts in the field of stream processing.
I worked for Telstra Corporation over 18 years. Before I joined Telstra, I had worked for many companies across different industries, such as software (artificial intelligence research), naval architecture, electronics, telecommunication, civil engineering, and space industry. In 2015, I started up my Ph.D. research journey under the supervision of Professors: Ramamohanarao Kotagiri and Rajkumar Buyya in Computing and Information Systems (CIS) /School of Engineering/The University of Melbourne.

My research interests include cloud pricing modeling, cloud market segmentation, cloud data center analysis, IT vendor management, cloud resource and capacity planning, data mining, machine learning algorithms, artificial intelligence, IT solution architecture, IT service delivery, and project management.

In Mar 2015, Prof Raj and I completed the book of Cloud Data Center Cost Modeling based on years’ experiences across different types of Telstra data centers (Cloud data centers, Next Generation multimedia data centers, enterprise business hosting data centers, and IT data centers).

In 2018, one of my papers was accepted:

Member Self Profile: Minxian Xu

I joined CLOUDS lab in October 2015, pursuing my PhD position under the supervision of Prof. Rajkumar Buyya at University of Melbourne. Before coming to Melbourne, I obtained both my bachelor and master degrees at University of Electronic Science and Technology of China (UESTC), both majoring in Software Engineering. During my graduate time, my research mainly focused on resource scheduling and load balancing in Cloud data centers. During my PhD candidature, I’m still working on resource scheduling, especially investigating energy efficient scheduling for Clouds. I have co-authored several papers by now. If you have interest, please find them below:


I have submitted my PhD thesis for examination at November 1\textsuperscript{st}, 2018 and worked as RA at CLOUDS lab. For more information, please visit my personal site: https://www.minxianxu.info/
Member Self Profile: Sara Kardani Moghaddam

I joined CLOUDS Lab as a PhD student in September 2015, under the supervision of Professor Ramamohanarao Kotagiri and Professor Rajkumar Buyya in the University of Melbourne. Prior to joining the CLOUDS Lab Group, I received my bachelor’s degree with First Class Honors from Shiraz University of Technology and after that I completed a master’s degree in information Technology at Sharif University of Technology. Before starting my PhD studies, I also worked for 3 years as a Software Designer and Developer in Iran.

My research interests include data analytics, anomaly detection, Cloud performance management and optimization techniques. Currently, I'm investigating the concepts of performance related anomalies and self-adaptable learning frameworks to find better ways of resource provisioning and auto-scaling in Cloud computing environment.
**Member Self Profile: Md. Redowan Mahmud**

I completed my BSc from Department of Computer Science and Engineering, University of Dhaka, Bangladesh in 2015. Later I was appointed as a lecturer in Department of Computer Science and Engineering, United International University, Bangladesh.

I have joined Cloud Computing and Distributed Systems (CLOUDS) Laboratory, Department of Computing and Information Systems, University of Melbourne, Australia in February, 2016. Here, I have been awarded with Melbourne International Research Scholarship (MIRS) and Melbourne International Fee Remission Scholarship (MIFRS) for supporting my studies.

Now, I am in final year of my PhD candidature and exploring resource management and application placement in Fog computing environment. Till date, I have authored 3 book chapter, 1 conference paper and 4 journal papers on Fog computing.

To follow my research activities, please visit

https://www.researchgate.net/profile/Md_Mahmud14 and
Member Self Profile: Muhammed Tawfiqul Islam

I have joined CLOUDS lab on July, 2016 as a PhD student. I am also a Lecturer at the Department of Computer Science & Engineering, University of Dhaka, Bangladesh and currently I am on a study leave. My research focus in PhD is on “SLA-based cloud resource management for Big Data Applications”.

Prior to finishing my BS and MS studies, I have worked as a software engineer in REVE systems, where I developed VOIP servers in H.323 and SIP protocols. In my MS research, I have worked in collaboration with Internet Society (ISOC) to fight for the cause “Net Neutrality”. I developed end-user applications to detect any blocking/shaping to Internet bandwidth/services by their Internet Service Providers (ISP) and this project was funded by ISOC Netherlands.

In the year 2018, I have published a book chapter and a journal paper (under review). Here is a list of publications I have finished during the first 2 years of my PhD:


Currently, I am working on the following projects:

- SLA-based Scheduling of Spark jobs in Heterogeneous Hybrid Cloud Environments
- SLA-based Adaptive Resource Management using Deep Reinforcement Learning
Member Self Profile: Muhammad Hafizhuddin Hilman

I joined CLOUDS Lab as a PhD student in January 2016 under the supervision of Prof. Rajkumar Buyya and Dr Amir Vahid Dastjerdi. I am working on Scientific Workflow Management under direct supervision from Research Fellow, Dr Maria A. Rodriguez. My area of interest includes Cloud Computing, Scientific Workflows, Cloud Scheduling, and Cloud Resource Management. As part of my PhD research, I investigate into the workflow as a service platform. Directly, putting scientific workflow computation into service that provides utility leasing for scientific users. I work on several algorithms on dynamic scheduling and resource provisioning for multiple workflows and modeling the workflow-as-a-service environment. List of my works during PhD are as follows:


I am currently staff-on-leave from Faculty of Computer Science, Universitas Indonesia. I got the scholarship from the Indonesian Government to pursue a PhD at the University of Melbourne. I got my bachelor and master degree from Universitas Indonesia in 2010 and 2012.

For further information, please refer to my Linkedin page https://www.linkedin.com/in/muhammadhilman/
Member Self Profile: Shashikant Ilager

I joined CLOUDS Lab as a PhD student in March 2017 under the supervision of Prof. Rajkumar Buyya and Prof. Rao Kotagiri at University of Melbourne.

Before joining CLOUDS lab, I received my Master of Technology (M.Tech) in Computer Science from the University of Hyderabad, India in 2016 and Bachelor of Engineering (B.E) from VTU, Karnataka, India in 2013. I also worked for a software company in India for a short period.

My PhD studies are supported by Melbourne Research Scholarship (MRS). During my PhD candidature, I am working on resource management techniques to optimize the energy consumption of cooling and computing systems of cloud data centers. Please find the recent published works below:


For more information, kindly visit the following pages.

Website: http://www.shashikantilager.com  
LinkedIn: https://www.linkedin.com/in/shashikantilager/
Member Self Profile: Tianzhang He

I joined CLOUDS lab in Aug 2017, pursuing my PhD position under the supervision of Prof. Rajkumar Buyya and Dr. Adel Nadjaran Toosi.

Before came to Melbourne, I obtained both my bachelor in 2014 in Computer Science and master degree in Computer System in 2017 at Northeastern University (NEU), China. During my graduate time, my research mainly focused on priority-based task scheduling algorithm and response time analysis in real-time systems. In my Master thesis, I analyse response time of OpenMP-based real-time tasks on multi-core systems and design a Benchmark tool called ompTG to transform OpenMP programs to the defined OpenMP-based DAG task model.

In my current research, the main topic includes Software-Defined Networking (SDN) and Network Function Virtualization (NFV) in terms of resource management in Cloud Data Centers to ensure the SLA. I investigate the live VM migration in SDN-enabled cloud data centers from the perspectives of computing resources, network resources and application’s QoS. This work can benefit the design of SLA-aware multiple live migration planning and live migration cost prediction that used in various resource scheduling policies, such as dynamic VNF/VM placement, consolidation algorithms, scheduled maintenance, etc. Furthermore, I am interested in dynamic VNF scheduling in edge computing environment.
Member Self Profile: Mohammad Goudarzi

I joined the CLOUDS Lab in July 2018 at the University of Melbourne as a PhD student under supervision of Prof. Rajkumar Buyya and Prof. Marimuthu Palaniswami. Previously, I graduated from Iran University of Science and Technology (IUST), Tehran, Iran, with First-Class Honors degree in M.Sc. in Information Technology, where I was awarded as the exceptional talented student as well. In My M.Sc. I worked on Mobile Cloud Computing as my thesis, and I published several research articles. Moreover, due to my academic achievements, I was awarded to become a member of Iranian National Elites Foundation, a prestigious organization for recognition and support of Iranian national elites, from which I received a prestigious research Grant. Besides, I have three years of experience working as a project manager of Internet of Things (IoT) and Location-Based Services (LBS) solutions in Iran. At the University of Melbourne, I passed all my PhD courses with the First-Class Honors grade, and also was awarded the Rowden White Scholarship, a prestigious scholarship provided by the University of Melbourne to talented, high quality PhD students. My research interests include IoT, Fog/Edge Computing, Distributed Systems, Wireless Communication, Optimization, and Data Analytics. Currently, I am investigating the concepts of Fog computing and IoT, and how we can provide end users with their desired services while guarantee the quality of service and experience.

For further information, you can check my LinkedIn Profile and Google Scholar page.
https://www.linkedin.com/in/mgoudarzi90/
https://scholar.google.com/citations?user=a7XqS_QAAAAJ&hl=en
Member Self Profile: Zhiheng Zhong

I started PhD degree in Clouds lab since July 2018, following a Samsung Kubernetes project conducted under the supervision of Prof Rajkumar Buyya and Dr Maria Rodriguez. I received my master’s degree in cloud computing from the University of Newcastle, UK and bachelor’s degree in Information and Computer Engineering from Nanchang University, China. After completing my master’s degree in 2015, I worked in Epam System as a software engineer for 6 months. Then I joined Morgan Stanley and worked as a Java Developer until Feb 2018, mainly responsible for development of trade surveillance application, like detecting market manipulation, ramping, handling high volumes of trading data processing.

My current research project is a prototype system for large-scale container orchestration based on Kubernetes platform. We aim to achieve cost efficiency and energy saving by supporting heterogeneous task configurations for container placements, and utilization optimization through cleaning unhealthy VM instances that are continuously suffering from low resource utilization by a rescheduling mechanism. We plan to build more pricing models and clearer benchmarks of QoS requirements in the future.
Visitor Self Profile: Satish Narayana Srirama

I am a Research Professor and the head of the Mobile & Cloud Lab at the Institute of Computer Science, University of Tartu, Estonia. My research focuses on cloud computing, mobile web services, mobile cloud, Internet of Things, fog computing, migrating scientific computing and enterprise applications to the cloud and large scale data analytics on the cloud. During April - August 2017 and also in Jan 2018, I have visited CLOUDS Lab as part of my sabbatical. During the visit, we have mainly collaborated in mobile cloud and fog computing domains. We have also co-ordinated in defining the manifesto for future generation cloud computing with the research focus at next decade.

Some of the joint publications are mentioned here:


Visitor Self Profile: Mohammadreza Razian

I received B.Sc. in Information Technology with rank 1th from Semnan University, Semnan, Iran in 2012. I received M.Sc. in Information Technology from Department of Computer Engineering, Sharif University of Technology, Tehran, Iran in 2014. During my research in master, I was working on data and computer networks security in Data and Network Security Laboratory (DNSL) of Sharif University of Technology. I was tutor of Computer Workshop and Computer Network lab in Sharif.

By the end of 2014 (I got Ranked 23th among more than 1000 participants in the entrance exam for Ph.D. position, 2014), I started my PhD studies at the Iran University of Science and Technology (IUST), Tehran, Iran, working in the areas of Cloud Computing. My PhD thesis focuses on investigating the methods for QoS-aware Service Composition for Cloud/IoT/Fog environments under uncertainty of QoS values. I joined the CLOUDS Lab in September 2018 as a research visitor at the University of Melbourne under the supervision of Professor Rajkumar Buyya. My research visit was sponsored by Ministry of Science, Research and Technology of Iran to carry part of ongoing Ph.D, and extended by Professor Buyya. Prior to joining the CLOUDS, I had solid experience in the industry, stepping from web development to computer network and web hardening. Furthermore, I was a lecturer in Sharif University of Technology and Semnan University for 1 and 3 years respectively. Generally, my research interests are Cloud Computing, IoT and Fog, Data and Computer Network Security.

For more information and publications, please visit my webpage: http://mrazian.com
**Visitor Self Profile: Wenjuan Li**

My name is Wenjuan Li, I'm an associate professor at Hangzhou Normal University, China. I joined CLOUDS lab in December 2017 as a visiting scholar under the supervision of Prof. Rajkumar Buyya at University of Melbourne. I also serve as a post doctor at Shanghai Jiao Tong University from October, 2015. I obtained my doctor degree form Zhejiang University, majoring in Computer Science and Technology. My research mainly focused on resource scheduling and service trust in cloud computing environments. Prof. Rajkumar Buyya is a very kind man, he gives me a lot of valuable advice on my research work. I spent an unforgettable and meaningful year in Melbourne. I submitted four papers during my stay in CLOUDS Lab. If you have interest, please find them below:

Visitor Self Profile: Vlado Stankovski

I am an associate professor of computer and information science at the University of Ljubljana, Slovenia. Areas of my interests include distributed, Grid and Cloud computing, and software engineering. I have worked on a variety of European Union funded research and innovation, technology integration projects, such as the DataMiningGrid (2004-2006), InteliGrid (2004-2007), mOSAIC (2011-2013), ENTICE (2015-2018) and SWITCH (2015-2018) projects. I am currently engaged in the new Horizon 2020 European Union – Korea project called DECENTER (2018-2021), which covers areas, such as the Internet of Things, Cloud, Fog and Edge computing, and Blockchain.

I am very grateful to my host professor Rajkumar Buyya who gave me an opportunity to stay with the CLOUDS Lab – a World renown research group – in the period from 1 July – 30 September 2018. I follow the work of prof. Rajkumar Buyya since 2004, when we used GridBus in our DataMiningGrid project. On this occasion, during my stay, I shared my experience in various projects with the members of CLOUDS Lab, and at the same time, I closely followed their ongoing research activities. I also engaged in some lecturing and tutoring as part of the M.Sc. course COMP90015 Distributed Systems.

This was an inspiring experience, and above all, I made some excellent new friends. In the CLOUDS Lab I felt like being at home. Dear colleagues and friends, you are always welcome in Slovenia!

Our 2018 publications include:

Visitor Self Profile: Shreshth Tuli

I joined CLOUDS lab as a research intern for 10 weeks (15 May – 25 July) under the supervision of Prof. Rajkumar Buyya. I am an undergraduate student at Indian Institute of Technology, Delhi and currently in the 3rd year of my course. My current research interests lie primarily in System design, Edge computing and Blockchain and during my visit to University of Melbourne, I developed FogBus framework. FogBus is an end-to-end integration framework for edge and cloud computing paradigms that is lightweight and supports blockchain based data integrity.

We have submitted a paper regarding our work to the Journal of Systems and Software, which is currently under review.

My GitHub profile: [https://github.com/shreshhtuli](https://github.com/shreshhtuli)
FogBus GitHub repository: [https://github.com/Cloudslab/FogBus](https://github.com/Cloudslab/FogBus)

Preprint of the paper:

8. Selected Projects/Programs

Cloudbus: A Toolkit for Market-Oriented Cloud Computing

Web: http://www.cloudbus.org/

The Cloud Computing and Distributed Systems (CLOUDS) Laboratory is a software research and innovation group at the University of Melbourne, Australia. The Lab is actively engaged in design and development of next-generation computing systems and applications that aggregate by dynamically leasing services of distributed resources depending on their availability, capability, performance, cost, and users' QoS requirements. The lab is working towards realising this vision through its two flagship projects: Gridbus and Cloudbus.

The Cloudbus project, an initiative that started in 2008 by the CLOUDS lab at the University of Melbourne, facilitates the realization of the above vision. The project developed innovative solutions for market-oriented Cloud computing. The current innovative developments include: (i) Aneka, a platform for developing and managing Cloud computing applications from market-oriented perspective; (ii) InterCloud, a framework for internetworking of Cloud service providers, dynamically creating federated computing environments, and scaling of distributed applications; (iii) CloudSim, a simulation framework that allows researchers to control every aspect of a Cloud environment: algorithms, platforms, and infrastructure; and (iv) Workflow Engine, a management platform that facilitates the creation, deployment and monitoring of complex applications modeled in a systematic and orderly manner in Cloud computing environments.

The Cloudbus project

The Cloudbus project is engaged in the creation of open-source specifications, architecture and a reference toolkit implementation for market-oriented cloud computing. Some of our technologies serve as foundation for industrial solutions offered by Manjrasoft to its customers worldwide.

The research probes include:
- Market Oriented Cloud Architecture
-Enterprise Cloud Application Platform (Aneka)
-Cloud Service Broker
-Cloud Workflows and Scheduling
-Service Level Agreements & Resource Allocation Systems (Libra).
-Energy-Efficient Data Centers and Clouds
-Cloud Simulation Toolkit (CloudSim).
-Application Development Environments
-Open SensorWeb Architecture
-InterCloud – Peering and Federation of Clouds
-Content Delivery Networks
-Software Defined Networks
-Big Data
-Internet of Things (IoT)
-Fog and Edge Computing
-Application Targets include: ECG Monitoring and Analysis, Data Mining and Business Analytics, Brain Imaging (Dartmouth Medical School), and Geophysics (Intrepid).

Future Research is Driven By:
A Manifesto for Future Generation Cloud Computing: Research Directions for the Next Decade.
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 / authorization 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.
- Cloudbrusting of application tasks across multiple Clouds (e.g., Azure and AWS)
Infrastructure-as-a-Service (IaaS) clouds offer several advantages for the deployment of scientific workflows. They enable Workflow Management Systems (WMSs) to access a flexible and scalable infrastructure by leasing Virtual Machines (VMs). This allows workflows to be easily packaged and deployed and more importantly, enables WMSs to access a virtually infinite pool of VMs that can be elastically acquired and released and are charged on a pay-per-use basis. In this way, cloud resources can be used opportunistically based on the number and type of tasks that need to be processed at a given point in time. This is a convenient feature as it is common for the task parallelism of scientific workflows to significantly change throughout their execution. The resource pool can be scaled out and in to adjust the number of resources as the execution of the workflow progresses. This facilitates the fulfillment of the quality-of-service (QoS) requirements by allowing WMSs to fine-tune performance while ensuring the available resources are efficiently used.

In this project we extend the Cloudbus WMS as a PaaS (Platform-as-a-Service) to support the cloud-computing paradigm. Specifically, the project aims to:

- Define an architectural framework and principles for the development of QoS-based workflow management in cloud environments,
- Develop QoS-based algorithms for scheduling scientific workflow applications,
- Develop policies and resource management algorithms tailored for the cloud resource model,
- Implement a prototype system by incorporating the algorithms and policies developed above, and
- Develop real world demonstrators in various scientific domains such as astronomy.

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


Web: http://www.cloudbus.org/greencloud

Traditionally, high-performance computing (HPC) community has focused on performance (speed). Since early 2000, several companies have started building Data Centers inspired by commodity HPC (cluster computing) systems-architecture for hosting/powering industrial applications including search engines such as Google. At the same time microprocessor vendors have not only doubled the number of transistors (and speed) every 18-24 months, but they have also doubled the power densities. That is, the tremendous increase in computer performance has come with an even greater increase in power usage. As a result operational cost of HPC systems including industrial Data Centre is rapidly growing. This is reflected from a statement by CEO of Google (Eric Schmit): "what matter most to Google is not speed but power, because data centers can consume as much electricity as a city."

The aim of Green Cloud Project is to develop high-end computing systems such as Clusters, Data Centers, and Clouds that allocate resources to applications hosting Internet services (e-Services) to meet not only users' quality of service requirements, but also minimise consumption of electric power. That is to, to improve power management and consumption by dynamically managing and configuring power-aware ability of system devices, such as processors, disks, and communication links.

Selected Publications:

CloudSim: A Framework for Modeling and Simulation of Cloud Computing Infrastructures and Services

Web: http://www.cloudbus.org/cloudsim

Cloud computing emerged as the leading technology for delivering reliable, secure, fault-tolerant, sustainable, and scalable computational services, which are presented as Software, Infrastructure, or Platform as services (SaaS, IaaS, PaaS). Moreover, these services may be offered in private data centers (private clouds), may be commercially offered for clients (public clouds), or yet it is possible that both public and private clouds are combined in hybrid clouds.

These already wide ecosystem of cloud architectures, along with the increasing demand for energy-efficient IT technologies, demand timely, repeatable, and controllable methodologies for evaluation of algorithms, applications, and policies before actual development of cloud products. Because utilization of real testbeds limits the experiments to the scale of the testbed and makes the reproduction of results an extremely difficult undertaking, alternative approaches for testing and experimentation leverage development of new Cloud technologies.

A suitable alternative is the utilization of simulations tools, which open the possibility of evaluating the hypothesis prior to software development in an environment where one can reproduce tests. Specifically in the case of Cloud computing, where access to the infrastructure incurs payments in real currency, simulation-based approaches offer significant benefits, as it allows Cloud customers to test their services in repeatable and controllable environment free of cost, and to tune the performance bottlenecks before deploying on real Clouds. At the provider side, simulation environments allow evaluation of different kinds of resource leasing scenarios under varying load and pricing distributions. Such studies could aid the providers in optimizing the resource access cost with focus on improving profits. In the absence of such simulation platforms, Cloud customers and providers have to rely either on theoretical and imprecise evaluations, or on try-and-error approaches that lead to inefficient service performance and revenue generation.

The primary objective of this project is to provide a generalized and extensible simulation framework that enables seamless modeling, simulation, and experimentation of emerging Cloud computing infrastructures and application services. By using CloudSim, researchers and industry-based developers can focus on specific system design issues that they want to investigate, without getting concerned about the low level details related to Cloud-based infrastructures such as Virtual Machines and Containers. CloudSim now support simulation of SDN and containers.

Some References:

- Jungmin Son and Rajkumar Buyya, CloudSimSDN-NFV: Modeling and Simulation of Network Function Virtualization and Service Function Chaining in Edge Computing Environments.
iFogSim: A Toolkit for Modeling and Simulation of Resource Management Techniques in Internet of Things, Edge and Fog Computing Environments

Web: http://www.cloudbus.org/cloudsim

Internet of Things (IoT) aims to bring every object (e.g. smart cameras, wearable, environmental sensors, home appliances, and vehicles) online, hence generating massive amounts of data that can overwhelm storage systems and data analytics applications. Cloud computing offers services at the infrastructure level that can scale to IoT storage and processing requirements. However, there are applications such as health monitoring and emergency response that require low latency, and delay caused by transferring data to the cloud and then back to the application can seriously impact their performances. To overcome this limitation, Fog computing paradigm has been proposed, where cloud services are extended to the edge of the network to decrease the latency and network congestion.

To realize the full potential of Fog and IoT paradigms for real-time analytics, several challenges need to be addressed. The first and most critical problem is designing resource management techniques that determine which modules of analytics applications are pushed to each edge device to minimize the latency and maximize the throughput. To this end, we need an evaluation platform that enables the quantification of performance of resource management policies on an IoT or Fog computing infrastructure in a repeatable manner.

We developed a simulator, called iFogSim, to model IoT and Fog environments and measure the impact of resource management techniques in terms of latency, network congestion, energy consumption, and cost.

Some References:

**FogBus: A Blockchain-based Lightweight Framework for Edge and Fog Computing**

Web: [https://github.com/Cloudslab/FogBus](https://github.com/Cloudslab/FogBus)

The requirement of supporting both latency sensitive and computing intensive Internet of Things (IoT) applications is increasing the necessity for integrating Edge, Fog and Cloud infrastructures. Since, the integrated environments are distributed, centralized management of its resources is not feasible when latency sensitive data load is very high. Heterogeneity of resources and communication model further obstruct smooth execution of applications in integrated environments. In addition, Security of data and resources is also a very major concern of integrated Fog-Cloud environments.

There exist several works implementing software frameworks for integrating IoT-enabled systems, Fog and Cloud infrastructure. They:

- Barely support simultaneous execution of multiple applications and platform independence.
- Offer narrow scope to application developers and users to tune them framework according to individual requirements.
- Apply centralized techniques that eventually increase management time and service delay.
- Considers a few security aspects.

To overcome these problems, we have developed a lightweight framework for integrating IoT devices, Fog Computing and Cloud infrastructures. It offers platform independent application execution and node-to-node interaction overcoming resource heterogeneity. Moreover, it incorporates a Platform-as-a-Service (PaaS) model that assists both application developers, users and services providers. Based on FogBus, we have also developed a prototype application system for Sleep Apnea analysis in integrated IoT-Fog-Cloud environment. Furthermore, for ensuring data security, FogBus implements Blockchain, encryption and digital signature techniques.

![High-level view of FogBus-enabled integrated computing environments.](image)

**References:**

9. Moments with Visitors, Colleagues and International Hosts

A snap of CLOUDS lab members taken during Jay’s PhD completion seminar (Jan 2018)

Lyon, France, February 27, 2018: With Laurent during visit to INRIA
Lyon, France, February 27, 2018: With Laurent and Marcos during visit to INRIA.

With Prof Tian, UESTC, Chengdu, China, after my seminar on May 10, 2018.
During a Open Day 2018 demo with Dean of Engineering (Aug 2018)

During a Open Day 2018 demo with Harald (Aug 2018)