Quantum Cloud Computing and Distributed Systems (qCLOUDS) Laboratory

www.cloudbus.org

Annual Report - 2024

School of Computing and Information Systems

Faculty of Engineering and Information Technology

The University of Melbourne, Australia

1. Director's Message

I am pleased to report on the key activities and outcomes of **Q**uantum **Clou**d Computing and **D**istributed **S**ystems (qCLOUDS) Laboratory at the University of Melbourne, Australia during the academic year 2024, 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-leaders in developing innovative solutions for Cloud Computing. The highlights of research activities and outcomes in 2024 are:

- The Lab successfully carried out ARC Discovery Project along with involvement in two large projects (especially Zero Net Emissions CRC for Agriculture and SPARC (Scheme for Promotion of Academic and Research Collaboration)).
- Members of the CLOUDS Lab have authored 59 publications, which include 36 journal papers and 14 conference papers.
- The Lab's flagship Cloudbus Project has released various new modules for CloudSim, iFogSim, and Fogbus. iFogSim, building on CloudSim, has emerged as a de-facto toolkit for modelling and simulation of Fog and Edge computing environments. We released two new Quantum computing software systems (qFaaS and iQuantum). They have been used by several researchers in academia and industries around the world.
- Members have presented over 56 invited talks that include 14 keynotes delivered at international conferences/events held in Australia, India, China, and Thailand.
- The Lab successfully hosted research activities of over 25 scholars, which include 19 PhD students and 4 Visiting Research Fellows.
- In 2024 alone, our papers have attracted over 10350 citations (ref: Google Scholar).
- We are recognised as the Top Researcher in "Software Systems" field (highest cited in top 20 journals over the past five years), The Australian Research Magazine 2025, The Australian, November 2024.
- A list of the world's top 2% researchers complied by Stanford University after assessing scientists worldwide for research carried out over their careers across all disciplines ranks us as #1 for citation impact for both single calendar year 2023 and career-long in Distributed Computing area.
- Members of the Lab have led community efforts such as (a) the organisation of conferences (e.g., CCGrid 2024 in USA and UCC 2024 in UAE) and (b) Editor-In-Chief of Journal of Software: Practice and Experience, which was established 55+ 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,

Dr. Rajkumar Buyya, Redmond Barry Distinguished Professor
Director, Quantum Cloud Computing and Distributed Systems (qCLOUDS) 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/Academics:

- Dr. Maria Rodriguez
- Dr. Muhammed Tawfiqul Islam
- Dr. Mohammed Goudarzi

PhD Students

- Mr. Jie Zhao
- Mr. Ming Chen
- Mr. Tharindu Bandara
- Mr. Siddharth Agarwal
- Mr. Hoa Nguyen
- Ms. Kalyani Pendyala
- Mr. Zhiyu Wang
- Ms. Duneesha Fernando
- Ms. Thakshila Imiya Mohottige
- Ms. Niloofar Gholipour
- Mr. Qifan Deng
- Mr. TianYu Qi
- Mr. Hootan Zhian
- Mr. Murtaza Rangwala

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

International Visitors
- Aletéia Araújo, Universidade de Brasília, Brasília, Brazil, Dec. 2023-Dec. 2024.
- Remo Andreoli, Sant'Anna School of Advanced Studies, Pisa, Italy, Feb.-July, 2024.
- Anwesha Mukherjee, Mahishadal Raj College, India, June-August 2024.
- Shi Dong, Zhoukou Normal University, China, June-Aug 2024.

3. Competitive Grants Funded Projects and Programs - Active

Australian Research Council (ARC)

- M. Gong; H. Bondell, R. Buyya, and K. Zhang, Causal Knowledge-Empowered Adaptive Federated Learning, Discovery Project, Australian Research Council (ARC), 2024-2026. Amount: $506,145

Other National Grants

- S. Ghosh (Indian lead) and R. Buyya (Australian lead), "AI-based Framework for Personalized Smart Healthcare using Edge-Cloud Platform", SPARC (Scheme for Promotion of Academic and Research Collaboration), Ministry of Education, Government of India, June 2024-May 2026, Amount: Indian Rupees 68.1 Lakh (68,10,000). AUD 126,100.

Industry and Melbourne University Grants

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4. Publications

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

Year Publication Type	2002	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24
Books/Proceedings	1	1	1	1	5	4	3	5	2	3	2	2	1	2	3	1	2	2	4	8	5	2	4
Journal Papers	6	1	4	5	6	4	10	13	8	9	15	17	17	17	24	31	43	47	36	42	52	26	36
Book Chapters	1	0	0	4	4	2	4	11	3	13	3	1	2	3	6	10	1	8	3	9	9	2	4
Conference Papers	4	7	9	16	15	24	22	27	15	14	12	6	14	21	9	11	15	20	12	10	3	10	14
Magazine Articles	0	0	1	2	4	2	0	1	2	1	0	5	2	3	1	1	1	0	1	1	0	0	0
Total	12	9	15	28	34	36	39	57	30	40	32	31	36	46	43	54	62	77	58	70	69	40	58

Books/Proceedings Edited

1. Rajkumar Buyya, Christian Vecchiola, Shivananda R. Poojara, Satish Narayana Srirama, and Thamarai Selvi, Mastering Cloud Computing: Powering AI, BigData, and IoT Applications, ISBN:9789355329509, McGraw Hill, New Delhi, India, April 2024.
2. Anwesha Mukherjee, Debashis De, and Rajkumar Buyya (eds.), Resource Management in Distributed Systems, 314 pages, ISBN: 978-981-97-2643-1, Springer, Singapore, June 2024.
3. Prodipto Das, Shahin Ara Begum, and Rajkumar Buyya (eds), Proceedings of the First International Conference Advanced Computing, Machine Learning, Robotics and Internet Technologies (AMRIT 2023, March 10-11, 2023, Silchar, India), ISBN: 978-3-031-47224-4, Springer, Germany, April 2024.
4. Rajkumar Buyya, Sudip Misra, Yiu-Wing Leung, and Ayan Mondal (eds), Proceedings of International Conference on Advanced Communications and Machine Intelligence (MICA 2022, December 9-11, 2022, Chennai, India), ISBN: 978-981-99-2770-8, Springer, Singapore, July 2024.

Book Chapters

1. Mohammad Goudarzi, Qifan Deng, and Rajkumar Buyya, Resource Management in Edge and Fog Computing using FogBus2 Framework, Managing Internet of Things Applications across Edge and Cloud Data Centres, ISBN: 978-1785617799, IET Press, UK, May 2024.
2. Anwesha Mukherjee, Debashis De, and Rajkumar Buyya, Cloud Computing Resource Management, Resource Management in Distributed Systems, A. Mukherjee, D. De, and R. Buyya (eds), 17-37pp, ISBN: 978-981-97-2643-1, Springer, Singapore, June 2024.
3. Maria R. Read, Chinmaya Dehury, Satish Narayana Srirama, and Rajkumar Buyya, Deep Reinforcement Learning (DRL)-Based Methods for Serverless Stream Processing Engines: A Vision, Architectural Elements, and Future Directions, Resource Management in Distributed Systems, A. Mukherjee, D. De, and R. Buyya (eds), 285-314pp, ISBN: 978-981-97-2643-1, Springer, Singapore, June 2024.
4. Shinu M. Rajagopal, Supriya M., Rajkumar Buyya, Blockchain Integrated Federated Learning in Edge-Fog-Cloud Systems for IoT based Healthcare Applications: A Survey, Federated Learning: Principles, Paradigms, and Applications, 237-269pp, J. Sahoo, M. Ouaissa, and Akarsh K. Nair (eds), ISBN: 978-177-49-1638-4, Apple Academic Press, Inc., Palm Bay, Florida, USA, September 2024.

Journal Papers

1. Mohammad Goudarzi, Maria A. Rodriguez, Majid Sarvi, and Rajkumar Buyya, u-DDRL: A QoS-Aware Distributed Deep Reinforcement Learning Technique for

Service Offloading in Fog computing Environments, IEEE Transactions on Mobile Computing (TMC), Volume 17, Number 1, Pages: 47-59, ISSN: 1536-1233, IEEE Computer Society Press, USA, January/February 2024.

2. Rajkumar Buyya, Shashikant Ilager, and Patricia Arroba, Energy-Efficiency and Sustainability in New Generation Cloud Computing: A Vision and Directions for Integrated Management of Data Centre Resources and Workloads, Software: Practice and Experience (SPE), Volume 54, Issue 1, Pages: 24-38, ISSN: 0038-0644, Wiley Press, New York, USA, January 2024.

3. Sukhpal Singh Gilla, Minxian Xu, Panos Patros, Huaming Wu, Rupinder Kaur, Kamalpreet Kaur, Stephanie Fuller, Manmeet Singh, Priyansh Arora, Ajith Kumar Parlikad, Vlado Stankovski, Ajith Abraham, Soumya K. Ghosh, Hanan Lutfiyya, Salil S. Kanhere, Rami Bahsoon, Omer Rana, Schahram Dustar, Rizos Sakellariou, Steve Uhlig, and Rajkumar Buyya, Transformative effects of ChatGPT on modern education: Emerging Era of AI Chatbots, Internet of Things and Cyber-Physical Systems, Volume 4, Pages: 19-23, ISSN: 2667-3452, Elsevier Press, Amsterdam, The Netherlands, January 2024.

4. Prabhakar Krishnan, Kurunandan Jain, Shivananda R. Poojara, Satish Narayana Srirama, Tulika Pandey, and Rajkumar Buyya, eSIM and Blockchain Integrated Secure Zero-Touch Provisioning for Autonomous Cellular-IoTs in 5G Networks, Computer Communications, Volume 216, Pages: 324-345, ISSN: 0140-3664, Elsevier Science, Amsterdam, The Netherlands, February 2024.

5. TianZhang He and Rajkumar Buyya, A Taxonomy of Live Migration Management in Cloud Computing, ACM Computing Surveys, Volume 56, No. 3, Article No. 56, Pages: 1-33, ISSN: 0360-0300, ACM Press, New York, USA, March 2024.

6. Zhiyu Wang, Mohammad Goudarzi, Mingming Gong, and Rajkumar Buyya, Deep Reinforcement Learning-based Scheduling for Optimizing System Load and Response Time in Edge and Fog Computing Environments, Future Generation Computer Systems, Volume 152, Pages: 55-69, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands, March 2024.

7. Dawei Sun, Chunlin Zhang, Shang Gao, and Rajkumar Buyya, An Adaptive Load Balancing Strategy for Stateful Join Operator in Skewed Data Stream Environments, Future Generation Computer Systems, Volume 152, Pages: 138-151, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands, March 2024.

8. Samodha Pallewatta, Vassilis Kostakos and Rajkumar Buyya, MicroFog: A Framework for Scalable Placement of Microservices-based IoT Applications in Federated Fog Environments, Journal of Systems and Software (JSS), Volume 209, Pages: 1-19, ISSN: 0164-1212, Elsevier Press, Amsterdam, The Netherlands, March 2024.

9. Sukhpal Singh Gill, Huaming Wu, Panos Patros, Carlo Ottaviani, Priyansh Arora, Victor Casamayor Pujol, David Haunschild, Ajith Kumar Parlikad, Oktay Cetinkaya, Hanan Lutfiyya, Vlado Stankovski, Ruidong Li, Yuemin Ding, Junaid Qadir, Ajith Abraham, Soumya K. Ghosh, Houbing Herbert Song, Rizos Sakellariou, Omer Rana, Joel J.P.C. Rodrigues, Salil S. Kanhere, Schahram Dustar, Steve Uhlig,

Kotagiri Ramamohanarao, and Rajkumar Buyya, Modern Computing: Vision and Challenges, Telematics and Informatics Reports, Volume 13, Pages: 1-38, ISSN: 2772-5030, Elsevier Press, Amsterdam, The Netherlands, March 2024.

10. Tharindu B. Hewage, Shashikant Ilager, Maria A. Rodriguez, and Rajkumar Buyya, CloudSim Express: A Novel Framework for Rapid Low Code Simulation of Cloud Computing Environments, Software: Practice and Experience (SPE), Volume 54, Issue 3, Pages: 483-500, ISSN: 0038-0644, Wiley Press, New York, USA, March 2024.

11. Naveen Chandra Gowda, Sunilkumar S. Manvi, A. Bharathi Malakreddy, and Rajkumar Buyya, TAKM-FC: Two-way Authentication with efficient Key Management in Fog Computing Environments, The Journal of Supercomputing, Volume 80, Number 5, Pages: 2412-2448, ISSN: 0920-8542, Springer Science+Business Media, Berlin, Germany, March 2024.

12. Amanda Jayanetti, Saman Halgamuge, and Rajkumar Buyya, Multi-Agent Deep Reinforcement Learning Framework for Renewable Energy-Aware Workflow Scheduling on Distributed Cloud Data Centers, IEEE Transactions on Parallel and Distributed Systems (TPDS), Volume 35, No. 4, Pages: 604-615, ISSN: 1045-9219, IEEE CS Press, USA, April 2024.

13. Guangyao Zhou, Wenhong Tian, Rajkumar Buyya, Ruini Xue, and Liang Song, Deep Reinforcement Learning-based Methods for Resource Scheduling in Cloud Computing: A Review and Future Directions, Artificial Intelligence Review, Volume 57, Pages: 1-42, ISSN: 0269-2821, Springer, New York, USA, April 2024.

14. Hoa T. Nguyen, Muhammad Usman, Rajkumar Buyya, QFaaS: A Serverless Function-as-a-Service framework for Quantum Computing, Future Generation Computer Systems (FGCS), Volume 154, Pages: 281-300, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands, May 2024.

15. Wuji Zhu, Mohammad Goudarzi, and Rajkumar Buyya, FLight: A Lightweight Federated Learning Framework in Edge and Fog Computing, Software: Practice and Experience (SPE), Volume 54, Issue 5, Pages: 813-841, ISSN: 0038-0644, Wiley Press, New York, USA, May 2024.

16. TianZhang He, Adel N. Toosi, and Rajkumar Buyya, Efficient Large-Scale Multiple Migration Planning and Scheduling in SDN-Enabled Edge Computing, IEEE Transactions on Mobile Computing (TMC), Volume 23, Number 6, Pages: 6667-6680, ISSN: 1536-1233, IEEE Computer Society Press, USA, June 2024.

17. Junhui Du, Huaming Wu, Minxian Xu, and Rajkumar Buyya, Computation Energy Efficiency Maximization for NOMA-Based and Wireless-Powered Mobile Edge Computing With Backscatter Communication, IEEE Transactions on Mobile Computing (TMC), Volume 23, Number 6, Pages: 6954-6970, ISSN: 1536-1233, IEEE Computer Society Press, USA, June 2024.

18. Guangyao Zhou, Yuanlun Xie, Haocheng Lan, WenHong Tian, Rajkumar Buyya, and Kui Wu, Information Interaction and Partial Growth-based Multi-population Growable Genetic Algorithm for Multi-dimensional Resources Utilization Optimization of Cloud Computing, Swarm and Evolutionary Computation, Volume

87, Pages: 1-23, ISSN: 2210-6502, Elsevier Press, Amsterdam, The Netherlands, June 2024.

19. Hoa T. Nguyen, Muhammad Usman and Rajkumar Buyya, iQuantum: A Toolkit for Modeling and Simulation of Quantum Computing Environments, Software: Practice and Experience (SPE), Volume 54, Issue 6, Pages: 1141-1171, ISSN: 0038-0644, Wiley Press, New York, USA, June 2024.

20. Dawei Sun, Yueru Wang, Jialiang Sui, Shang Gao, Jia Rong, and Rajkumar Buyya, Lc-Stream: An Elastic Scheduling sTrategy with Latency Constraints in Geo-Distributed Stream Computing Environments, Concurrency and Computation: Practice and Experience (CCPE), Volume 36, No. 14, Pages: 1-22, ISSN: 1532-0626, Wiley Press, New York, USA, June 2024.

21. Mangala N., Naveen D.R., B. Eswara Reddy, Rajkumar Buyya, Venugopal K.R., S.S. Iyengar, and L.M. Patnaik, Secure Pharmaceutical Supply Chain using Blockchain in IoT Cloud Systems, Internet of Things, Volume 26, Pages: 1-28, ISSN: 2542-6605, Elsevier, Amsterdam, The Netherlands. July 2024.

22. Tanushree Dey, Somnath Bera, Bachchu Paul, Debashis De, Anwesha Mukherjee, and Rajkumar Buyya, Fly: Femtolet-based Edge-Cloud Framework for Crop Yield Prediction using Bidirectional Long Short-Term Memory, Software: Practice and Experience (SPE), Volume 58, Issue 8, Pages: 1295-1589, ISSN: 0038-0644, Wiley Press, New York, USA, August 2024.

23. Jing Bi, Haisen Ma, Haitao Yuan, Rajkumar Buyya, Jinhong Yang, Jia Zhang, and MengChu Zhou, Multivariate Resource Usage Prediction with Frequency-Enhanced and Attention-Assisted Transformer in Cloud Computing Systems, IEEE Internet of Things Journal, Volume 11, Number 15, Pages: 26419-26429, ISSN: 2327-4662, IEEE Computer Society Press, USA, August 2024.

24. Bivasa Ranjan Parida, Amiya Kumar Rath, Bibudhendu Pati, Chhabi Rani Panigrahi, Hitesh Mohapatra, Tien-Hsiung Weng5, and Rajkumar Buyya, SSEPC Cloud: Carbon Footprint Aware Power Efficient Virtual Machine Placement in Cloud Milieu, Journal of Computer Science and Information Systems, Volume 21, Issue 3, Pages: 759-780, ISSN: 1820-0214, ComSIS Consortium Press, Novi Sad, Serbia, July-September 2024.

25. Muhammad Zakarya, Lee Gillam, Ayaz Ali Khan, Omer Rana, and Rajkumar Buyya, ApMove: A Service Migration Technique for Connected and Autonomous Vehicles, IEEE Internet of Things Journal, Volume 11, Number 17, Pages: 28721-28733, ISSN: 2327-4662, IEEE Computer Society Press, USA, September 2024.

26. Siddharth Agarwal, Maria A. Rodriguez, and Rajkumar Buyya, A Deep Recurrent-Reinforcement Learning Method for Intelligent AutoScaling of Serverless Functions, IEEE Transactions on Services Computing (TSC), Volume 17, Number 5, Pages: 1899-1910, ISSN: 1939-1374, IEEE Computer Society Press, USA, Sept.-Oct. 2024.

27. Haitao Yuan, Meijia Wang, Jing Bi, Shuyuan Shi, Jinhong Yang, Jia Zhang, MengChu Zhou, and Rajkumar Buyya, Cost-Efficient Task Offloading in Mobile Edge Computing With Layered Unmanned Aerial Vehicles, IEEE Internet of Things

Journal, Volume 11, Number 19, Pages: 30496-30509, ISSN: 2327-4662, IEEE Computer Society Press, USA, October 2024.

28. Dawei Sun, Haiyang Chen, Shang Gao, and Rajkumar Buyya, Orchestrating Scheduling, Grouping and Parallelism to Enhance the Performance of Distributed Stream Computing System, Expert Systems with Applications Journal, Volume 254, Pages: 1-17, ISSN: 0957-4174, Elsevier Press, Amsterdam, The Netherlands, November 2024.

29. Patricia Arroba, Rajkumar Buyya, Roman Cardenas, Jose L. Risco-Martin, and Jose M. Moya, Sustainable Edge Computing: Challenges and Future Directions, Software: Practice and Experience (SPE), Volume 54, Issue 11, Pages: 2272-2296, ISSN: 0038-0644, Wiley Press, New York, USA, November 2024.

30. Zinuo Cai, Zebin Chen, Xinglei Chen, Ruhui Ma, Haibing Guan, and Rajkumar Buyya, SPSC: Stream Processing Framework atop Serverless Computing for Industrial Big Data, IEEE Transactions on Cybernetics, Volume 55, Number 11, Pages: 6509-6517, ISSN: 2168-2267, IEEE Systems, Man, and Cybernetics Society, New York, USA, November 2024.

31. Haoyu Bai, Minxian Xu, Kejiang Ye, Rajkumar Buyya, and Chengzhong Xu, DRPC: Distributed Reinforcement Learning Approach for Scalable Resource Provisioning in Container-based Clusters, IEEE Transactions on Services Computing (TSC), Volume 17, Number 6, Pages: 3437-3484, ISSN: 1939-1374, IEEE Computer Society Press, USA, Nov.-Dec. 2024.

32. Minghui Wu, Dawei Sun, Shang Gao, Keqin Li, and Rajkumar Buyya, Elastic Scaling of Stateful Operators Over Fluctuating Data Streams, IEEE Transactions on Services Computing (TSC), Volume 17, Number 6, Pages: 3555-3568, ISSN: 1939-1374, IEEE Computer Society Press, USA, Nov.-Dec. 2024.

33. Shi Dong, Junxiao Tang, Khushnood Abbas, Ruizhe Hou, Joarder Kamruzzaman, Leszek Rutkowski, and Rajkumar Buyy, Task Offloading Strategies for Mobile Edge Computing: A Survey, Computer Networks, Volume 254, Pages: 1-25, ISSN: 1389-1286, Elsevier Press, Amsterdam, The Netherlands, December 2024.

34. Samodha Pallewatta, Vassilis Kostakos, and Rajkumar Buyya, Reliability-aware Proactive Placement of Microservices-based IoT Applications in Fog Computing Environments, IEEE Transactions on Mobile Computing (TMC), Volume 23, Number 12, Pages: 11326-11341, ISSN: 1536-1233, IEEE Computer Society Press, USA, December 2024.

35. Ankur Nahar, Koustav Kumar Mondal, Debasis Das, and Rajkumar Buyya, Clouds on the Road: A Software-Defined Fog Computing Framework for Intelligent Resource Management in Vehicular Ad-hoc Networks, IEEE Transactions on Mobile Computing (TMC), Volume 23, Number 12, Pages: 12778-12792, ISSN: 1536-1233, IEEE Computer Society Press, USA, December 2024.

36. Xiaoyu Xia, Feifei Chen, Qiang He, Ruikun Luo, Bowen Liu, Caslon Chua, Rajkumar Buyya, Yun Yang, EdgeShield: Enabling Collaborative DDoS Mitigation at the Edge, IEEE Transactions on Mobile Computing (TMC), Volume 23, Number 12, Pages: 14502-14513, ISSN: 1536-1233, IEEE Computer Society Press, USA, December 2024.

Conference Papers

1. Hoa T. Nguyen, Muhammad Usman, and Rajkumar Buyya, DRLQ: A Deep Reinforcement Learning-based Task Placement for Quantum Cloud Computing, Proceedings of the 2024 IEEE International Conference on Cloud Computing (CLOUD 2024, IEEE CS Press, USA), ShenZhen, China, July 7-13, 2024.

2. Satish Kumar, Renyu Yang, Rajiv Ranjan Singh, Rami Bahsoon, Jie Xu, and Rajkumar Buyya, MatchCom: Stable Matching-Based Software Services Composition in Cloud Computing Environments, Proceedings of the 24th International Conference on Web Engineering (ICWE 2024, Springer, Germany), Tampere, Finland, June 17-20, 2024.

3. Zia Ur Rehman, Saif ul Islam, Uzair Hassan, Jalil Boudjadar, and Rajkumar Buyya, Improving CNN Model Training Time Efficiency using MPI-driven Parallelization and Ensemble Learning, Proceedings of the 2024 International Conference on AI and the Digital Economy (CADE 2024, IET Press, UK), ISBN: 978-1-83724-184-2, Venice, Italy, June 24-26, 2024.

4. Siddharth Agarwal, Maria A. Rodriguez, and Rajkumar Buyya, On-demand Cold Start Frequency Reduction with Off-Policy Reinforcement Learning in Serverless Computing, Proceedings of the 2024 International Conference on Computational Intelligence and Data Analytics (ICCIDA 2024, Springer, Singapore), Hyderabad, India, June 28-29, 2024. - **Keynote Paper**.

5. Amanda Jayanetti, Saman Halgamuge, and Rajkumar Buyya, A Deep Reinforcement Learning Approach for Cost Optimized Workflow Scheduling in Cloud Computing Environments, Proceedings of the 2024 Asia Pacific Conference on Computing Technologies, Communications and Networking (CTCNET 2024, ACM Press, New York, USA), Chengdu, China, July 26-27, 2024.

6. Kalyani Pendyala and Rajkumar Buyya, An Infrastructure Cost Optimised Algorithm for Partitioning of Microservices, Proceedings of the 6th Asia Conference on Machine Learning and Computing (ACMLC 2024, ISBN: 979-8-4007-1001-8, ACM Press, USA), Bangkok, Thailand, July 26-28, 2024.

7. Sandeep Saharan, Seema Bawa, Neeraj Kumar, and Rajkumar Buyya, Foggy-Park: A Dynamic Pricing and NSGA based Allocation Scheme for On-Street Parking System, Proceedings of the SIGCOMM 2024 Workshop on Zero Trust Architecture for Next Generation Communications (ZTA-NextGen 2024, ISBN: 979-8-4007-0715-5, ACM Press, USA), Sydney, Australia, August 4-8, 2024.

8. Shashikant Ilager and Rajkumar Buyya, Machine Learning in Energy and Thermal-aware Resource Management of Cloud Data Centers: A Taxonomy and Future Directions, Proceedings of the 19th Conference on Computer Science and Information Systems (FedCSIS 2021, IEEE Press, USA), Sofia, Bulgaria, September 8-11, 2024. - **Invited Paper**.

9. Xueyuan Han, Zinuo Cai, Yichu Zhang, Chongxin Fan, Junhan Liu, Ruhui Ma and Rajkumar Buyya, Hermes: Memory-Efficient Pipeline Inference for Large Models on Edge Devices, Proceedings of the 42nd IEEE International Conference on

Computer Design (ICCD 2024, IEEE CS Press, USA), Milan, Italy, November 18-20, 2024.

10. Alain Hennebelle, Qifan Dieng, Leila Ismail, and Rajkumar Buyya, SmartEdge: Smart Healthcare End-to-End Integrated Edge and Cloud Computing System for Diabetes Prediction Enabled by Ensemble Machine Learning, Proceedings of the 16th IEEE International Conference on Cloud Computing Technology and Science (CloudCom 2019, IEEE CS Press, USA), Abu Dhabi, UAE, December 9-11, 2024.

11. Dawei Sun, Zhongyuan Zhao, Yueru Wang, Shang Gao, and Rajkumar Buyya, A Task Dependency-Aware Scheduling Strategy for Cross-Domain Stream Computing Environments, Proceedings of the 26th IEEE International Conferences on High Performance Computing and Communications (HPCC 2024, IEEE CS Press, USA), Wuhan, China, December 13-15, 2024.

12. Duneesha Fernando, Maria A. Rodriguez and Rajkumar Buyya, iAnomaly: A Toolkit for Generating Performance Anomaly Datasets in Edge-Cloud Integrated Computing Environments, Proceedings of the 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024, IEEE CS Press, USA), Sharjah, UAE, December 16-19, 2024.

13. Siddharth Agarwal, Maria A. Rodriguez and Rajkumar Buyya, Input-Based Ensemble-Learning Method for Dynamic Memory Configuration of Serverless Computing Functions, Proceedings of the 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024, IEEE CS Press, USA), Sharjah, UAE, December 16-19, 2024.

14. Joao Bachiega Jr, Breno Costa, Michel J. F. Rosa, Leonardo R. Carvalho, Marcelo A. Marotta, Aleteia Araujo and Rajkumar Buyya, A Cost-Efficient Resource Allocation for Fog Computing with Users and Providers Perspective, Proceedings of the 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024, IEEE CS Press, USA), Sharjah, UAE, December 16-19, 2024.

5. Invited Presentations and Outreach

By the Lab Director:

Keynote Talks at International Conferences

1. 8th International Conference on Emerging Applications of Information Technology (EAIT 2024), Kolkata, India, January 12-13, 2024.
2. 20th International Conference on Distributed Computing and Intelligent Technology (ICDCIT-2024), Bhubaneswar, India, January 17-20, 2024.
3. 16th International Conference on Computer and Automation Engineering (ICCAE 2024), Melbourne, Australia, March 14-17, 2024.
4. 5th International Conference on Innovative Trends in Information Technology, Kottayam, Kerala, India, March 15-16, 2024.
5. 4th International Conference on Emerging Trends and Technologies on Intelligent Systems (ETTIS 2024), New Delhi, India, March 27-28, 2024.
6. 2nd IEEE International Conference on Knowledge Engineering and Communication Systems (ICKECS 2024), Chikballapur, India, April 18-19, 2024.
7. 2nd International Conference On Mobile Internet, Cloud Computing and Information Security (MICCIS 2024), Changsha, China, April 19-21, 2024.
8. 6th International Conference on Electrical Engineering and Information & Communication Technology (ICEEICT), Dhaka, Bangladesh, May 2-4, 2024.
9. 4th International Conference on Information Communication and Software Engineering (ICICSE 2024), Beijing, China, May 10-12, 2024.
10. 2024 International Conference on Modeling, Natural Language Processing, and Machine Learning (CMNM 2024), Xi'an, China, May 17-19, 2024.
11. International Conference on Computational Intelligence and Data Analytics (ICCIDA 2024), Hyderabad, India, June 28-29, 2024.
12. IEEE International Conference on Cloud Computing (CLOUD 2024), ShenZhen, China, July 7-13, 2024.
13. CCF Chips 2024 Conference, Shanghai, China, July 19-20, 2024.
14. 2024 Asia Pacific Conference on Computing Technologies, Communications and Networking (CTCNET 2024), Chengdu, China, July 26-27, 2024.
15. 6th Asia Conference on Machine Learning and Computing (ACMLC 2024), Bangkok, Thailand, July 26-28, 2024.
16. 14th International Conference on Software Technology and Engineering (ICSTE 2024), Macau, China, August 16-18, 2024.
17. International Conference on Sustainable Solutions in Engineering and Technology (SSET 2024), Bagalkote, India, August 29-30, 2024.
18. Second International Conference on Advanced Computing, Machine Learning, Robotics and Internet Technologies (AMRIT-2024), Agartala, India, November 8-9, 2024.
19. 2nd International Conference on Artificial Intelligence, Computing Technologies, Internet of Things, and Data Analytics (AICTA 2024), Raipur, India, Nov. 15-17, 2024.
20. International Conference on Data Science and Communication (ICTDSC - 2024), Siliguri, India, November 21-22, 2024.
21. International Conference on Smart Systems and Wireless Communication (SSWC 2024), Kalyani, India, November 29-30, 2024.
22. Macao Symposium on Cloud Computing and Intelligent Driving (CCID 2024), Macau, China, December 6-7, 2024.
23. 4th International Conference on Communication and Network Security, Xiamen, China, December 6-8, 2024.

24. 20th International Conference on Frontiers of Information Technology (FIT 2024), Islamabad, Pakistan, December 9-10, 2024.
25. 12th International Conference on Big Data and Artificial Intelligence (BDA 2024), Hyderabad, India, December 17-20, 2024.
26. 5th International Conference on Computational Intelligence (ICCI 2024), Surat, India, December 24-26, 2024.

National Conferences

1. National Workshop on Cloud Computing and AI Applications, Karnataka College, Bidar, India, Jan. 29, 2024.
2. International Symposium on Cloud, Quantum Computing, and AI Applications, Bidar, India, July 1-3, 2024.
3. National Workshop on Cloud and Quantum Accelerated Computing, Kochi, India, December 18, 2024.

Seminars - in Cloud and Quantum Computing area:

1. Indian Institute of Technology (IIT), Kharagpur, India, January 10, 2024.
2. Symbiosis University, Nagpur, India, January 12, 2024.
3. St. Vincent Pallotti College of Engineering and Technology, Nagpur, India, January 16, 2024.
4. The University of Hyderabad, Hyderabad, India, January 19, 2024.
5. Institute of Aeronautical Engineering, Hyderabad, India, January 22, 2024.
6. South Asian University, Delhi, India, January 24, 2024.
7. Bennett University, Noida, India, February 29, 2024.
8. The University of Hyderabad, Hyderabad, India, June 26, 2024.
9. Institute of Aeronautical Engineering (IARE), Hyderabad, India, June 27, 2024.
10. GND Engineering College, Bidar, India, June 29, 2024.
11. KIIT University, Bhubaneswar, India, July 1, 2024.
12. Indian Institute Technology (IIT), Bhubaneswar, India, July 2, 2024.
13. Ramadevi Women's University, Bhubaneswar, India, July 5, 2024.
14. Chinese Academy of Sciences, ShenZhen, China, July 12, 2024.
15. Beihang University, Beijing, China, July 15, 2024.
16. China Telecom, Beijing, China, July 15, 2024.
17. Beijing University of Technology, Beijing, China, July 16, 2024.
18. Shanghai Jiao Tong University (SJTU), Shanghai, China, July 18, 2024.
19. University of Electronic Science and Technology of China, Chengdu, China, July 22, 2024.
20. Chulalongkorn University, Bangkok, Thailand, July 26, 2024.
21. Shenzhen Institute of Advanced Technology, Shenzhen, China, December 4, 2024.
22. National Institute of Technology, Trichy, India, December 10, 2024.
23. Thiagarajar College of Engineering (TCE), Madurai, India, December 12, 2024.
24. Kalasalingam Academy of Research and Education, Srivilliputhur, India, December 13, 2024.
25. Indian Institute of Science Education and Research (IISER), Thiruvananthapuram, India, December 16, 2024.
26. G Pulla Reddy Engineering College, Kurnool, India, December 21, 2024.
27. Karnataka Arts, Science and Commerce College, Bidar, India, December 23, 2024.
28. Institute of Aeronautical Engineering, Hyderabad, India, December 27, 2024.

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

Journal Editorials
1. Editorial Board Member, *International Journal of Parallel, Emergent and Distributed Systems (IJPEDS)*, ISSN: 1744-5760, Taylor & Francis Group, UK, 2013-to date.
2. Field Chief Editor, Frontiers in the Internet of Things, Frontiers Media, Lausanne, Switzerland, 2022 - to date.
3. Associate Editor, ACM Transactions on Autonomous and Adaptive Systems (TAAS), ISSN:1556-4665, ACM Press, New York, USA, 2024- to date.

Conference Steering Committee
1. Founder and Chair, IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing (CCGrid), 2001-to date.
2. Advisory 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.
4. Member, International Symposium on Computer Architecture and High Performance Computing, Brazil, 2005-to date.
5. Founder and Chair, IEEE/ACM International Conference on Utility and Cloud Computing (UCC) series, 2009-to date.

Conference Organisation/Program Committee Memberships

1. 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024), December 16-19, 2024. Sharjah, UAE.
2. IEEE International Conference on Web Services (ICWS 2024), July 7-13, 2024, Shenzhen, China.
3. IEEE International Conference on Cloud Computing (CLOUD 2024), July 7-13, 2024, Shenzhen, China.

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/cluster

By Other Members:

Technical Program Committee Memberships + other Professional Services
* Noted in their profile pages.

7. Members Profile and Activities

Member Self Profile: Jie Zhao

I joined the qCLOUDS Lab in July 2020 at the University of Melbourne as a PhD student, under the supervision of Prof. Rajkumar Buyya and Dr Maria Rodriguez Read. My study is funded by the Melbourne Research Scholarship (MRS).

In 2005, I received my bachelor's degree in Electronic Engineering and Information Technology from Shanghai Normal University. After graduation, I worked for two years as a software engineer in Shanghai and Beijing until 2007. In July 2007, I came to Australia and completed a master's degree in information technology at the University of Melbourne in 2009.

Before joining the CLOUDS lab, I worked ten years for a mid-size IT retailer enterprise in different roles as a senior software engineer, an IT infrastructure manager, and a CTO. I'm also an AWS certified solution architect. During my industry experience, I used hybrid-cloud and multi-cloud strategies to empower critical infrastructure and business applications, adopted Kubernetes and various cloud-native technologies, and successfully transformed a monolithic architecture into a modern microservice oriented architecture.
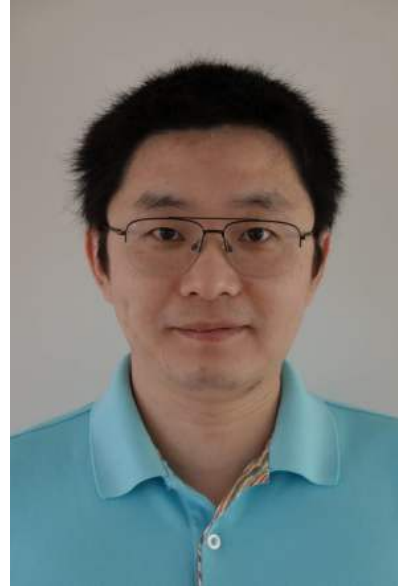
During my industry career, I developed vital interests in resource management and cloud computing. Remembering inspirations given by Prof. Buyya during my master's degree study, I came to him for pursuing a PhD. Currently, my research interest lies in the middle ground of cloud computing, resource management, artificial intelligence, and operations research. The broad goal is to identify and fill research gaps in AI/ML-powered autonomous workload management, resource management and operation in cloud computing environments.

Publications:

Jie Zhao, Maria A. Rodriguez, and Rajkumar Buyya, High-Performance Mining of COVID-19 Open Research Datasets for Text Classification and Insights in Cloud Computing Environments, Proceedings of the 13th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2020, IEEE CS Press, USA), Leicester, UK, Dec. 7-10, 2020.

Jie Zhao, Maria A. Rodriguez, and Rajkumar Buyya, A Deep Reinforcement Learning Approach to Resource Management in Hybrid Clouds Harnessing Renewable Energy and Task Scheduling, Proceedings of the 14th IEEE International Conference on Cloud Computing (IEEE Cloud 2021, IEEE CS Press, USA), September 5-10, 2021.

Profiles:
Linked In: https://www.linkedin.com/in/jie-zhao-64843765/
Website: https://jiezhao.net/

Member Self Profile: Ming Chen

I joined the CLOUDS Lab as a Ph.D. student in January 2021, under the supervision of Prof. Rajkumar Buyya, Dr. Maria Alejandra Rodriguez, and Dr. Tawfiq Islam. Prior to embarking on my Ph.D. journey, I earned my Bachelor's degree in Engineeringfrom Hunan University in September 2016. Subsequently, I worked as a research engineer and project manager at the Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences. My previous work encompassed fields such as speech recognition, FinTech, and Cloud Robotics. Currently, my research at the University of Melbourne primarily focuses on microservice scheduling, networking and LLMs.

Outside the lab, my hobbies include tennis, snooker, surfing, and hiking.

Paper in 2024:

Chen, Ming, Muhammed Tawfiqul Islam, Maria Rodriguez Read, and Rajkumar Buyya. "TraDE: Network and Traffic-aware Adaptive Scheduling for Microservices Under Dynamics." arXiv preprint arXiv:2411.05323 (2024). (Under review in IEEE Transactions on Parallel and Distributed Systems)

For more information, please refer,
Linkedin : https://www.linkedin.com/in/ming-chen-6056b4b9/
Google Scholar : https://scholar.google.com.au/citations?user=KGdnd20AAAAJ&hl=en

Member Self Profile: Qifan Deng

I obtained a bachelor of engineering and a bachelor of management at the Beijing Institute of Technology. After that, I worked as a research assistant in Beijing Measurement and Control Technology Lab, as an engineer at Intel Corporation, as a software engineer at Huawei, and as a digital analyst at McKinsey & Company.

I joined the CLOUDS Laboratory in November 2020, as a master majoring in computer science at University of Melbourne.

I am ready to start my Ph.D. under the supervision of Rajkumar Buyya, working on a scalable distributed framework for scheduling and processing Internet of Things requests.

I hope my work can help with people's efficiency and creativity, thus, leave a small footprint as a contribution to human civilization progress.

GitHub: https://github.com/pancak3
LinkedIn: https://linkedin.com/in/qifan-deng

Member Self Profile: Siddharth Agarwal

I joined CLOUDS lab as a Master of Science (Computer Science) student in March 2020, under the supervision of Dr. Buyya and Dr. Maria Rodriguez at The University of Melbourne.

Prior to joining the CLOUDS Lab Group, I received my Bachelor of Technology degree with Honours from Jaypee Institute of Information Technology (JIIT), India, where I gained initial experiences in the field of AI/ML along with practical implementations. After graduating, I worked with IBM India for 15 months as an Associate System Engineer at Bangalore, India, with a focus towards software development and management of CMS (Content Management System) applications.

I completed my MSc mostly from overseas (India) in 2021, obtaining a place in Dean's Honors List 2021 and was awarded a Melbourne Research Scholarship for my Doctoral program. As part of my PhD program, I am currently exploring the resource management and resource scheduling techniques in the domain of Serverless computing or Function-as-a-Service offering of Cloud Computing and investigating the application of AI/ML techniques for the same. My research focuses on data-driven and workload-aware function resource configurations and management.

My recent research publications are as follows –

1. **Siddharth Agarwal**, Maria A. Rodriguez, and Rajkumar Buyya, A Deep Recurrent-Reinforcement Learning Method for Intelligent AutoScaling of Serverless Functions, IEEE Transactions on Services Computing (TSC), Volume 17, Number 5, Pages: 1899-1910, ISSN: 1939-1374, IEEE Computer Society Press, USA, Sept.-Oct. 2024.
2. **Siddharth Agarwal**, Maria A. Rodriguez, and Rajkumar Buyya, On-demand Cold Start Frequency Reduction with Off-Policy Reinforcement Learning in Serverless Computing, Proceedings of the 2024 International Conference on Computational Intelligence and Data Analytics (ICCIDA 2024, Springer, Singapore), Hyderabad, India, June 28-29, 2024.
3. **Siddharth Agarwal**, Maria A. Rodriguez and Rajkumar Buyya, Input-Based Ensemble-Learning Method for Dynamic Memory Configuration of Serverless Computing Functions, Proceedings of the 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024, IEEE CS Press, USA), Sharjah, UAE, December 16-19, 2024.

For further information, please refer to my LinkedIn page:
www.linkedin.com/in/siddharth26agarwal

Member Self Profile: Nguyen Thanh Hoa

I joined qCLOUDS Labs in October 2021 to pursue my PhD under the supervision of Prof. Rajkumar Buyya and A/Prof. Muhammad Usman. My PhD study is fully funded by the Vingroup Scholarship, managed by Vin University, Vietnam. Before starting the PhD research, I obtained my Bachelor of Engineering in Computer Networks and Communications and my Master's in Computer Science (majoring in Cybersecurity) from Vietnam National University - Ho Chi Minh City (VNU-HCM) in 2016 and 2019, respectively. After graduating in 2016, I have 5+ year teaching experience at the University of Information Technology, VNU-HCM. Besides, I also spent 5 months working as a research intern on the topic of Serverless and Multi-Access Edge Computing at the National Institute of Informatics (NII) in Tokyo, Japan in 2020.

My research interests include Quantum Cloud Computing, Reinforcement Learning, Quantum Software Engineering, Quantum Machine Learning and Quantum Cybersecurity. At qCLOUDS Lab, I have been working on the Ph.D. research topic "Resource Orchestration Algorithms and Systems for Quantum Cloud Computing," focusing on designing efficient practical and simulation frameworks and techniques to optimize resource orchestration and management for quantum computation tasks in cloud-based environments.

For more information about my research, publications, and networking, please refer to my LinkedIn and my website https://hoaio.com/research

Member Self Profile: Tharindu B. Hewage

I joined the qCLOUDs Lab in 2021 to pursue my doctoral degree under the supervision of Prof. Rajkumar Buyya Dr. Shashikant Ilager and Dr. Maria A. Rodriguez. Before joining the lab, I worked as a Senior IAM R&D Engineer at WSO2, an open-source middleware company.

I am currently in the final year of my Ph.D., focusing on carbon-aware resource management in latency-sensitive cloud environments. My research involves designing efficient resource management algorithms and system architectures to reduce both the operational and embodied carbon footprint of latency-sensitive applications. Further details, including my published works, preprints, and open-source software, are available on my personal website.

Personal Website: https://hewage.io/

Research interests: **Systems Research, Cloud Computing, Sustainable Computing**

Member Self Profile: Kalyani Pendyala

I am a PhD student part of CLOUDS LAB since January 2022

As part of Initial research work, I have started with a broader area of Software engineering and Cloud optimization. With Green Cloud and resource optimization as the larger goals of research my particular interest is around software architecture and software engineering methodologies to contribute the cloud resource optimization.

Spent a quality time on literature review around the most widely used Microservices architecture evolution, working in Microservices and efficient ways of partitioning, placement, provisioning of Microservices.

I strongly believe optimization of resources shouldn't be confined to infrastructure and below layers, but it needs to be a responsible part of all peripheral layers like software application/ architecture and even software development principles.

Member Self Profile: Zhiyu Wang

I am a PhD student at the qCLOUDS Lab, University of Melbourne, supervised by Professor Rajkumar Buyya, Dr. Mingming Gong, and Dr. Mohammad Goudarzi. I joined the lab in 2022 to pursue my doctoral research in AI-driven solutions for edge and cloud computing.

Prior to my PhD, I obtained my Master's degree from the University of Melbourne in 2021, where I completed my thesis under the supervision of Professor Rajkumar Buyya.

My research explores the application of AI in optimizing edge and cloud computing. My broader interests include machine learning, the Internet of Things (IoT), and distributed systems.

My paper published in 2024 is:

Zhiyu Wang, Mohammad Goudarzi, Mingming Gong, and Rajkumar Buyya, Deep Reinforcement Learning-based Scheduling for Optimizing System Load and Response Time in Edge and Fog Computing Environments, Future Generation Computer Systems, Volume 152, Pages: 55-69, ISSN: 0167-739X, Elsevier Press, Amsterdam, The Netherlands, March 2024.

For more details, feel free to visit my Google Scholar page or connect with me on LinkedIn.

Member Self Profile: Duneesha Fernando

I joined the qCLOUDS lab in April 2022, to pursue my PhD under the supervision of Prof. Rajkumar Buyya and Dr. Maria Rodriguez Read. My PhD study is fully funded by the Melbourne Graduate Research Scholarship.

In 2019, I completed my BSc (Hons) in Computer Science degree at the University of Colombo School of Computing (UCSC), Sri Lanka. Afterwards, I held the position of Assistant Lecturer at the same university for 1 year. Thereafter, I joined WSO2 which is world's #1 open source integration vendor and served its research team for 2 years, first as a Research Engineer, and then as a Senior Machine Learning Engineer.

At WSO2, I was a member of the team that developed a performance anomaly detection solution for microservices deployed in its EiPaaS platform. I commenced my PhD studies with the aim of further exploring along this research direction while building up on the practical knowledge already gained from the software industry.

My research interests include, performance anomaly detection, resource management, cloud/ edge/ fog computing and microservice-based IoT application development. In my PhD research, I'm working on anomaly-aware management of microservices-based IoT applications in edge computing environments. I'm particularly interested in addressing unique research challenges that arise when developing an autonomous anomaly-aware framework for the management of microservices-based IoT applications in edge computing environments.

Following are the outcomes of my PhD so far,
1) Efficient Training Approaches for Performance Anomaly Detection Models in Edge Computing Environments (journal paper, under 2nd review) - https://arxiv.org/abs/2408.12855
2) iAnomaly: A Toolkit for Generating Performance Anomaly Datasets in Edge-Cloud Integrated Computing Environments (Published at the 17th IEEE/ACM International Conference on Utility and Cloud Computing - UCC'24) - https://arxiv.org/abs/2411.02868

For more information please refer,
Linkedin : https://www.linkedin.com/in/duneesha-fernando/
Google Scholar : https://scholar.google.com.au/citations?user=azM61FMAAAAJ&hl=en

Member Self Profile: Thakshila Dilrukshi

I joined the CLOUDS Lab in November 2022 as a Ph.D. student Under the supervision of Professor Rajkumar Buyya and Associate Professor Artem Polyvyanny. I obtained my Master's in Computer Science degree specializing in Software Architecture, and my BSc Engineering (Hons) degree, specializing in Computer Science from the University of Moratuwa, Sri Lanka. Before joining the CLOUDS Lab, I worked in a leading IT company related to financial markets in Sri Lanka for 9 years.

Currently, I'm in the first year of my Ph.D. my research area is microservices and process mining. The project is mainly focusing on redesigning the legacy software into microservices by analyzing the software logs.

For more information, please refer: https://www.linkedin.com/in/thakshilad/

Member Self Profile: Tianyu Qi

I joined the qCLOUDS lab as a PhD student in June 2023 under the supervision of Dr. Maria Read and Prof. Rajkumar Buyya. I obtained my Bachelor of Engineering in Electronics Engineering from China Agricultural University in 2019 and my Master of Science in Computer Science from the University of Melbourne in 2021. Before joining CLOUDS lab, I worked in Industry as a Java Developer in my country.

In my master's degree, supervised by Dr. Maria Read, my research project topic is resource allocation for Distributed Stream Processing Systems. I am in the first year of my PhD study, whose research is on Serverless Computing for Stream Processing. My research aims to achieve lower latency and higher throughput for stream processing applications.

Publications:
Tianyu Qi and Maria Rodriguez. 2021. A Traffic and Resource Aware Online Storm Scheduler. In Proceedings of the 2021 Australasian Computer Science Week Multiconference (ACSW '21). Association for Computing Machinery, New York, NY, USA, Article 8, 1–10.

My 2024 work is accepted for presentation in CCGrid 2025 conference.

Profiles:
Email: tiqi@student.unimelb.edu.au

Member Self Profile: Murtaza Rangwala

I am a Ph.D. candidate in the School of Computing and Information Systems at the University of Melbourne, affiliated with the qCLOUDS Lab and supervised by Professor Rajkumar Buyya and Professor Richard Sinnott. My research focuses on enhancing privacy and trust in decentralized and federated learning systems.

I developed TrustMesh, a blockchain-based framework for secure distributed computing in IoT environments, which was accepted at the 22nd IEEE International Conference on Software Architecture. I am currently building Murmura, a peer-to-peer learning simulator to evaluate decentralized algorithms across network topologies and privacy constraints. My work is supported by the Melbourne Graduate Research Scholarship. I also volunteer as a Peer Reviewer for the IEEE/ACM Transactions on Networking journal.

I hold a Bachelor of Software Engineering from Monash University Malaysia, where I designed a blockchain-based energy trading platform in collaboration with Tenaga Nasional, Malaysia's largest energy provider. Prior to my PhD, I worked on modernizing cloud infrastructure as an Engineering Analyst at Goldman Sachs, focusing on scalable solutions for private wealth management.

I aim to advance federated learning systems that prioritize privacy and trustworthiness, enabling entities to collaborate securely without compromising sensitive data.

LinkedIn: https://www.linkedin.com/in/murtazahrangwala
Website: https://www.murtaza-hatim.com

Research Visitor: Aletéia Patrícia Favacho de Araújo

I joined the CLOUDS Lab in January 2024 as an international research visitor with the collaboration of Prof. Rajkumar Buyya. My research was partially financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) from Brasil.

During my postdoctoral internship at the University of Melbourne, I published three articles co-authored by Prof. Rajkumar. Among these, two were in international events: "*A Cost-Efficient Resource Allocation for Fog Computing with Users and Providers Perspective*" – In the 17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024); and "*An Effective Resource Discovery Strategy for Fog Computing Driven by Computational Capabilities and Behavioral Characteristics*" – In the 8th International Conference on Information and Computer Technologies. The third paper was the chapter *"Observability in Fog Computing"* in the book "Springer Handbook of Data Engineering". In addition to these publications, during this period, two other articles were submitted to international journals, which are currently under analysis. Another significant achievement during this internship was reaching 1,000 citations from Google Scholar.

I am an Associate Professor at the Department of Computing Science at the University of Brasília (https://www.cic.unb.br/en/), Brazil. My research interests include Distributed Systems, Cloud/Fog/Edge Computing, Internet of Things (IoT), and Serverless computing or Function-as-a-Service (FaaS), publishing over 150 papers in peer reviewed conferences and journals. My research has influenced the state of the art in two ways. First, fundamental contributions to Computing Science have expanded the state of knowledge in Cloud/Fog/Edge Computing and Function-as-a-Service. Second, my work has impacted researchers in science and engineering, both nationally and internationally, supporting them in achieving excellence in their own disciplines.

I have advised 5 PhD students, 20+ MSc students, and 30+ graduation students. In addition, I coordinate the National Digital Girls Program of the Brazilian Computer Society (https://meninas.sbc.org.br/), which aims to encourage the participation of girls and women in computing. This is important because we need more women working in the computing area.

Further information can be found on my Google Scholar(https://scholar.google.com.br/citations?user=xuUFn-sAAAAJ&hl=pt-BR) page and on my CV http://lattes.cnpq.br/1566076687226024.

Research Visitor: Remo Andreoli

I'm Remo Andreoli, PhD student at RETIS Lab, Sant'Anna School of Advanced Studies (Pisa, Italy). I enjoy tackling both theoretical (i.e., optimization, performance modeling) and applied (i.e., network programming, performance tuning) research challenges in the systems area. My contributions seek to directly address industrial needs and achieve impactful outcomes through practical evaluations and/or integrations with open-source software, such as Kubernetes. Under the supervision of Tommaso Cucinotta and in collaboration with Ericsson Research, I investigate on the efficient orchestration of cloud services with latency and temporal constraints from a system-level perspective.

In 2024, I spent a semester at University of Melbourne under the supervision of Rajkumar Buyya, working on the re-engineering of CloudSim's internals for seamless integration between CloudSim extensions. The core architecture has been modernized, slimmed down (more than 13000 lines of code removed), partially re-written, and significantly optimized, reducing total heap memory allocated by 25% and simulation time by 12%. Moreover, module developers can now integrate, and customize as needed, the essential building blocks of CloudSim, such as physical hosts, VMs and scheduling policies, containers, power-awareness and simple network modeling, within the same simulated scenario.

CloudSim 7G's Full Release Note: https://github.com/Cloudslab/cloudsim/releases/tag/7.0
CloudSim 7G's Internals: https://onlinelibrary.wiley.com/doi/full/10.1002/spe.3413

I co-authored 12 research papers and won a Best Student Paper award at CLOSER 2021 for my first research project on priority-based performance differentiation within MongoDB.

Research Visitor: Dr. Anwesha Mukherjee

I have joined the CLOUDS Lab, at The University of Melbourne, as a Research Visitor for June 2024 to August 2024, under the supervision of Prof. Rajkumar Buyya. My research visit was funded by an Australian Research Council Project on Federated Learning.

I received my PhD (CSE) degree from Maulana Abul Kalam Azad University of Technology, West Bengal, India, in 2018. I received INSPIRE Fellowship from Department of Science & Technology, Govt. of India, to pursue my PhD, under the supervision of Prof. Debashis De. After PhD, I worked as a Research Associate in the project "National Geo-spatial Chair Professorship Award" (sponsored by Department of Science & Technology, Govt. of India), under the supervision of Prof. Soumya Kanti Ghosh, Department of Computer Science & Engineering, Indian Institute of Technology Kharagpur. Presently, I am working as an Assistant Professor and Head of the Department of Computer Science, Mahishadal Raj College (Govt. Sponsored), Mahishadal, West Bengal, India. I have received Young Scientist Award from International Union of Radio Science (H.Q. Belgium) in 2014, 2020, and 2021. I am a co-author of more than ninety research publications including International journals, book chapters, and conference proceedings. Among them, twenty research papers were published in collaboration with Prof. Rajkumar Buyya. I have also three edited books in collaboration with Prof. Rajkumar Buyya.

Presently, my research focuses on federated learning, edge computing, and Internet of Things.

During my visit in the CLOUDS Lab, I have proposed and implemented federated learning models for smart agricultural application. Further, I have proposed and implemented energy-efficient federated learning model for resource-limited mobile devices.

From the work during visit in the CLOUDS Lab, I have co-authored the following papers:
1. Anwesha Mukherjee and Rajkumar Buyya, "Federated Learning Architectures: A Performance Evaluation With Crop Yield Prediction Application," Software: Practice and Experience, Wiley, 2025, http://doi.org/10.1002/spe.3416.
2. Anwesha Mukherjee and Rajkumar Buyya, "EnFed: An Energy-aware Opportunistic Federated Learning in Resource Constrained Environments for Human Activity Recognition", https://arxiv.org/abs/2412.00768.
3. Anwesha Mukherjee and Rajkumar Buyya, "A Joint Time and Energy-Efficient Federated Learning-based Computation Offloading Method for Mobile Edge Computing", https://arxiv.org/abs/2409.02548.
4. Tanushree Dey, Somnath Bera, Anwesha Mukherjee, Debashis De, and Rajkumar Buyya, "FLyer: Federated Learning-based Crop Yield Prediction for Agriculture 5.0," IEEE Transactions on Artificial Intelligence, 2025, https://doi.org/10.1109/TAI.2025.3534149
5. Sushovan Khatua, Anwesha Mukherjee, Debashis De, Soumya K. Ghosh, and Rajkumar Buyya "EVerGen: Optimal Path Planning for Electric Vehicle using Modified Genetic Algorithm in Internet of Vehicular Things", IEEE Transactions on Vehicular Technology (revision submitted).
6. Somnath Bera, Tanushree Dey, Anwesha Mukherjee, Debashis De, and Rajkumar Buyya, "GenFed: Generative AI and Federated Learning-based Sustainable Soil Health Monitoring".

Research Visitor: Shi Dong

I joined the CLOUDS Lab. at the University of Melbourne as a visitor scholar, under the supervision of Professor Rajkumar Buyya in 2024. My research was funded by the Study Abroad Science & technology activity project in Henan Province and China Scholarship Council (CSC). During the visiting period, my research plan is to study the security task offloading of edge computing based on federated learning. I have published a survey paper on edge computing task offloading in cooperation with Professor Buyya as follows:

Dong, S., Tang, J., Abbas, K., Hou, R., Kamruzzaman, J., Rutkowski, L., & **Buyya, R.** (**2024**). Task offloading strategies for mobile edge computing: A survey. *Computer Networks*, 110791.

I received the M.S. degrees in Computer Application Technology from University of Electronic Science and Technology of China, Chengdu, China, in 2009, mentor Prof. Guangchun Luo, and the Ph.D. degree in Computer Application Technology from School of Computere Science and Engineering, Southeast University, Nanjing, China, in 2013. From July 2014 to April 2017, I was a Postdoctoral fellow (advised by Prof. Ruixuan Li) at State Key Laboratory of intelligent and Distribution System, Huazhong University of Science and Technology, Wuhan, China.

I am currently a Professor (Graduate Supervisor) at School of Computer Science and Technology, Zhoukou Normal University, Zhoukou, China. My current research focuses on edge computing, network security, pattern recognition, deep learning, blockchain, Internet of things, etc. I have published more than 160 papers in related academic journals and conferences. I am an associate Editor for IEEE Systems Journal(SCI index), Physical Communication(SCI index), PeerJ Computer Science(SCI index), IET Wireless Sensor Systems(EI index), IET Networks(EI index), IEICE Transactions on Communications(SCI index), Journal of Artificial Intelligence and Soft Computing Research(SCI index) and International Journal on Artificial Intelligence Tools(SCI index). I was awarded the Third Prize of Henan Science and Technology Progress Award (2018) and the academic technology leader of Henan Education Department (2019). I am currently the leader of the innovative network and Information Security Science and technology team of Henan Province, the leader of the provincial key discipline of computer application technology of Henan Province, and a supervisor of the master's degree students of the Hubei University of Technology and Wuhan Textile University. I am selected as one of the top 2% of scientists in the world in terms of 2023.

For more information please refer,
My website: https://njbsok.github.io/
Google Scholar: https://scholar.google.com/citations?user=yE4WT_0AAAAJ&hl=zh-CN&oi=ao

8. Selected Projects/Programs

Cloudbus: A Toolkit for Market-Oriented Cloud Computing

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

The Quantum 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: Cloudbus and iQuantum.

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 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
- InterCloud – Peering and Federation of Clouds
- Software Defined Networks
- Big Data
- Internet of Things (IoT)
- Fog and Edge Computing
- Application Targets include: Deed Learning, ECG Monitoring & Analysis, Data Mining & Business Analytics, and Brain Imaging (Dartmouth Medical School).
- Artificial intelligence (AI) for Next-Gen Cloud Computing
- Quantum Computing

Future Research is Driven By:

A Manifesto for Future Generation Cloud Computing: Research Directions for the Next Decade,

Aneka: .NET-based Cloud Computing

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 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)

- In 2024, we released Aneka 6.0 edition and updated to the latest .NET framework.
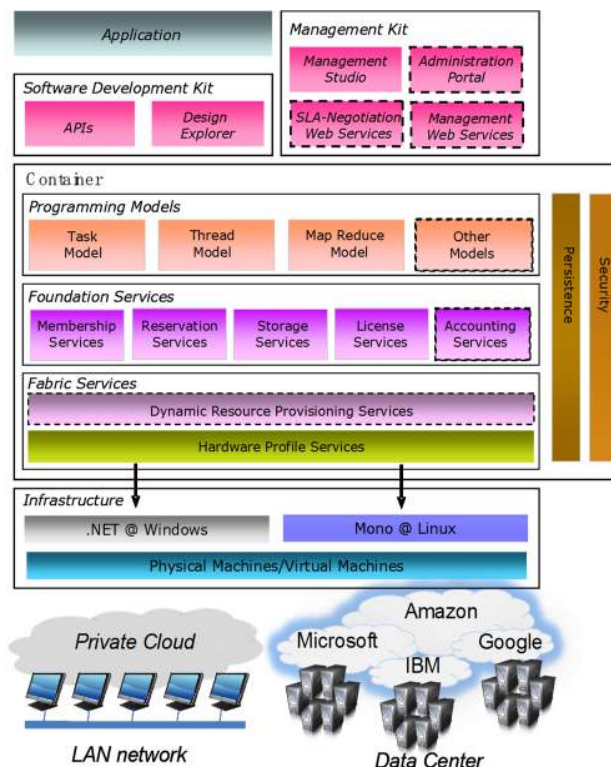
Aneka Architecture

A new edition of book with Aneka examples: Rajkumar Buyya, Christian Vecchiola, Shivananda Poojara, Satish Srirama, and Thamarai Selvi, Mastering Cloud Computing: Powering AI, BigData, and IoT Applications, ISBN: 9355329504, McGraw Hill, New Delhi, India, June 2024.

QoS-Oriented Cloud Workflow Engine

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

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 fulfilment of the quality-of-service (QoS) requirements by allowing WMSs to fine-tune performance while ensuring the available resources are efficiently used.

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
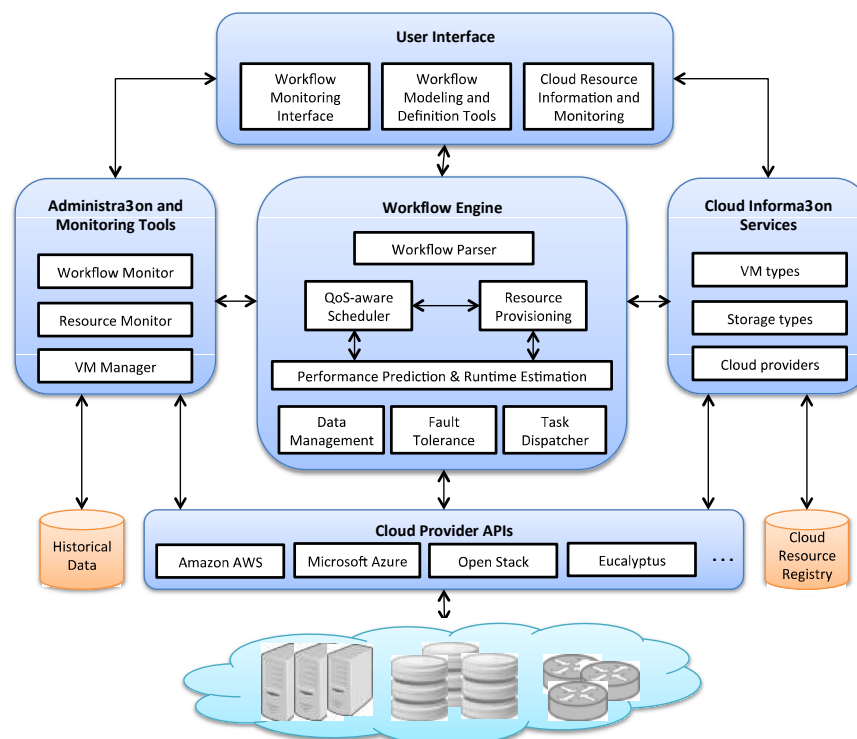- Develop real world demonstrators in various scientific domains such as astronomy.

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

Some References:

- Amanda Jayanetti, Saman Halgamuge, and Rajkumar Buyya, Multi-Agent Deep Reinforcement Learning Framework for Renewable Energy-Aware Workflow Scheduling on Distributed Cloud Data Centers, IEEE Transactions on Parallel and Distributed Systems (TPDS), Volume 35, No. 4, Pages: 604-615, ISSN: 1045-9219, IEEE CS Press, USA, April 2024.
- Muhammad Hilman, Maria Rodriguez, and Rajkumar Buyya, Workflow-as-a-Service Cloud Platform and Deployment of Bioinformatics Workflow Applications, Knowledge Management in Development of Data-Intensive Software Systems, I. Mistrik, M. Galster, B. Maxim, B. Tekinerdogan (eds), 205-228pp, ISBN: 978-1-003-00118-8, CRC Press, USA, June 2021.

The Green Cloud Project: Innovative Solutions for Energy-Efficient Cloud Computing

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:

- Anton Beloglazov and Rajkumar Buyya, Managing Overloaded Hosts for Dynamic Consolidation of Virtual Machines in Cloud Data Centers Under Quality of Service Constraints, IEEE Transactions on Parallel and Distributed Systems (TPDS), Volume 24, No. 7, Pages: 1366-1379, IEEE CS Press, Los Alamitos, CA, USA, July 2013.
- Shashikant Ilager, Rajeev Muralidhar, Kotagiri Rammohanrao, and Rajkumar Buyya, A Data-Driven Frequency Scaling Approach for Deadline-aware Energy Efficient Scheduling on Graphics Processing Units (GPUs), Proceedings of the 20th IEEE/ACM International Symposium on Cluster, Cloud, and Internet Computing (CCGrid 2020, IEEE CS Press, USA), Melbourne, Australia, May 11-14, 2020.
- Shashikant Ilager, Kotagiri Ramamohanarao, and Rajkumar Buyya, Thermal Prediction for Efficient Energy Management of Clouds using Machine Learning, IEEE Transactions on Parallel and Distributed Systems (TPDS), Volume 32, No. 5, Pages: 1044-1056, ISSN: 1045-9219, IEEE CS Press, USA, May 2021.
- Shashikant Ilager, Adel N. Toosi, Mayank Raj Jha, Ivona Brandic, Rajkumar Buyya, A Data-driven Analysis of a Cloud Data Center: Statistical Characterization of Workload, Energy and Temperature, Proceedings of the 16th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2023, IEEE CS Press, USA), Messina, Italy, December 4-7, 2023.
- Rajkumar Buyya, Shashikant Ilager, and Patricia Arroba, Energy-Efficiency and Sustainability in New Generation Cloud Computing: A Vision and Directions for Integrated Management of Data Centre Resources and Workloads, Software: Practice and Experience (SPE), Volume 54, Issue 1, Pages: 24-38, ISSN: 0038-0644, Wiley Press, New York, USA, January 2024.

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.

Since its inception in 2009, CloudSim has become the most widely used framework for modeling and simulation of Cloud computing environments. Thousands of researchers have extended its core functionalities to accommodate the rapid evolution of the Cloud Computing paradigm, from simple machine virtualization to modern serverless platforms, fostering the creation of a rich ecosystem of extensions. A recent release CloudSim 7G, the biggest re-engineering of the codebase to date. The core architecture has been modernized, slimmed down (more than 13000 lines of code removed!) and refactored to facilitate the integration of multiple CloudSim extensions within the same simulated environment.

Some References:
- Rodrigo N. Calheiros, Rajiv Ranjan, Anton Beloglazov, Cesar A. F. De Rose, and Rajkumar Buyya, CloudSim: A Toolkit for Modeling and Simulation of Cloud Computing Environments and Evaluation of Resource Provisioning Algorithms, Software: Practice and Experience (SPE), 41(1): 23-50, ISSN: 0038-0644, Wiley Press, New York, USA, January, 2011.
- Remo Andreoli, Jie Zhao, Tommaso Cucinotta, and Rajkumar Buyya, CloudSim 7G: An Integrated Toolkit for Modeling and Simulation of Future Generation Cloud Computing Environments, Software: Practice and Experience (SPE), ISSN: 0038-0644, Wiley Press, New York, USA (in press, accepted on Jan 9, 2025).

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.

In 2021: We released iFogSim 2.0 software.

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- Harshit Gupta, Amir Vahid Dastjerdi , Soumya K. Ghosh, and Rajkumar Buyya, iFogSim: A Toolkit for Modeling and Simulation of Resource Management Techniques in Internet of Things, Edge and Fog Computing Environments, Software: Practice and Experience, Volume 47, Issue 9, Pages: 1275-1296, Wiley Press, New York, USA, September 2017.
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- Redowan Mahmud and Rajkumar Buyya, Modelling and Simulation of Fog and Edge Computing Environments using iFogSim Toolkit, Fog and Edge Computing: Principles and Paradigms, R. Buyya and S. Srirama (eds), ISBN: 978-111-95-2498-4, Wiley Press, New York, USA, January 2019.
- Mohammad Goudarzi, Huaming Wu, Marimuthu Palaniswami, and Rajkumar Buyya, An Application Placement Technique for Concurrent IoT Applications in Edge and Fog Computing Environments, IEEE Transactions on Mobile Computing (TMC), Volume 20, Number 4, Pages: 1298-1311, ISSN: 1536-1233, IEEE Computer Society Press, USA, April 2021.
- Redowan Mahmud, Samodha Pallewatta, Mohammad Goudarzi, and Rajkumar Buyya, iFogSim2: An Extended iFogSim Simulator for Mobility, Clustering, and Microservice Management in Edge and Fog Computing Environments, Journal of Systems and Software (JSS), Volume 190, Pages: 1-17, ISSN: 0164-1212, Elsevier Press, Amsterdam, The Netherlands, August 2022.

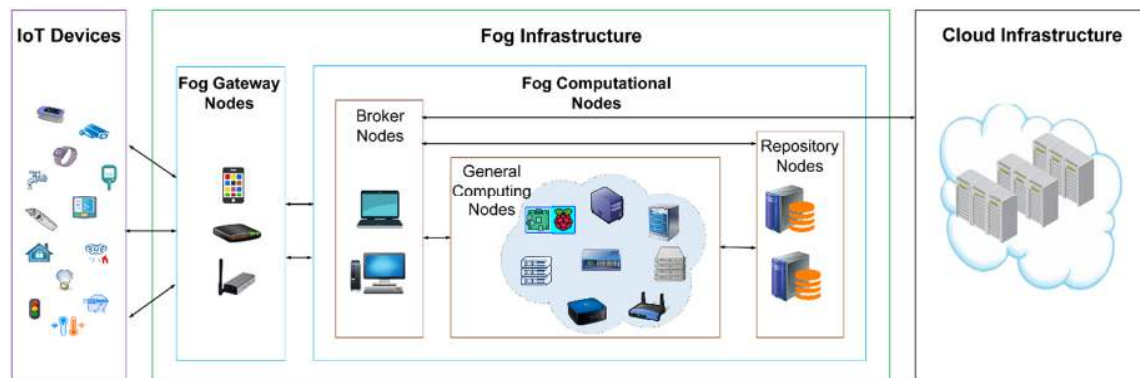# FogBus: A Blockchain-based Lightweight Framework for Edge and Fog Computing

Web: 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 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.
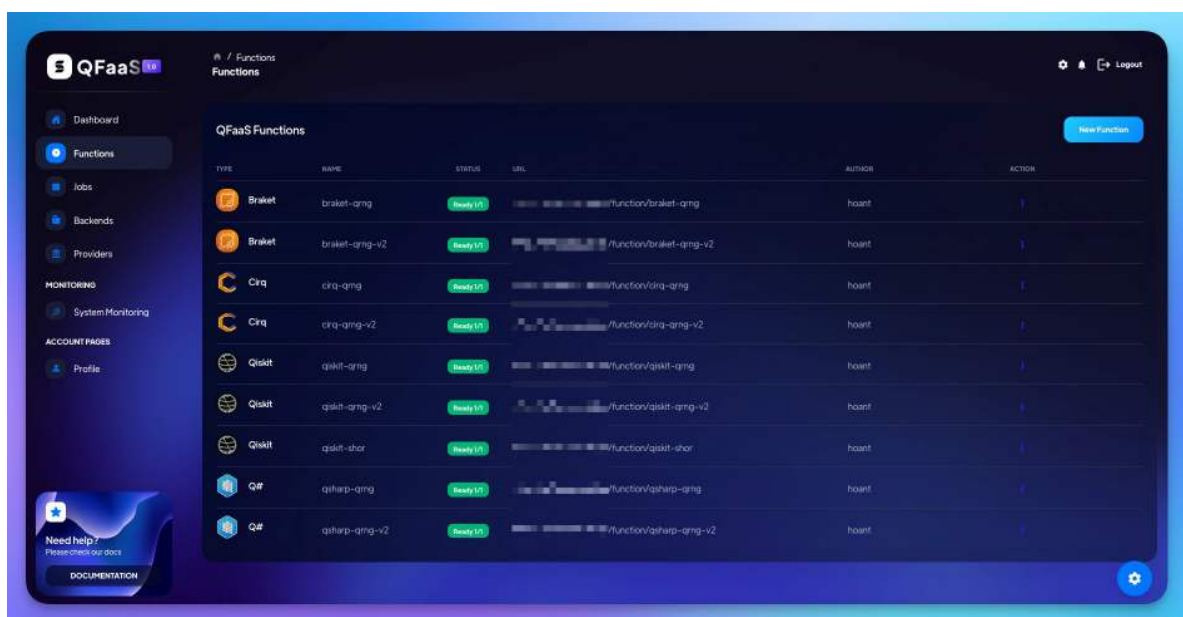

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[1] Shreshth Tuli, Redowan Mahmud, Shikhar Tuli, and Rajkumar Buyya, FogBus: A Blockchain-based Lightweight Framework for Edge and Fog Computing, Journal of Systems and Software (JSS), Volume 154, Pages: 22-36, Elsevier Press, Amsterdam, The Netherlands, August 2019.

[2] Shreshth Tuli, Nipam Basumatary, and Rajkumar Buyya, EdgeLens: Deep Learning based Object Detection in Integrated IoT, Fog and Cloud Computing Environments, Proceedings of the 4th IEEE International Conference on Information Systems and Computer Networks (ISCON 2019, IEEE Press, USA), Mathura, India, November 21-22, 2019.

[3] Qifan Deng, Mohammad Goudarzi and Rajkumar Buyya, FogBus2: A Lightweight and Distributed Container-based Framework for Integration of IoT-enabled Systems with Edge and Cloud Computing, Proceedings of the SIGMOD 2021 International Workshop on Big Data in Emergent Distributed Environments (BiDEDE 2021, ACM Press, USA), Xi'an, China, June 20-25, 2021.

QFaaS - A Serverless Quantum Function-as-a-Service Framework

QFaaS is a Quantum Function-as-a-Service framework that leverages the advantages of the serverless computing model and state-of-the-art software engineering techniques to advance practical quantum computing in the Noisy Intermediate-Scale Quantum (NISQ) era. Our framework provides essential elements of a serverless quantum system to streamline service-oriented quantum application development in cloud environments, such as combining hybrid quantum-classical computation, automating the backend selection, and adapting Quantum DevOps workflow. QFaaS offers the first full-stack and unified quantum serverless platform by integrating multiple well-known quantum software development kits, quantum simulators, and quantum cloud providers (IBM Quantum and Amazon Braket).

Highlights

- A comprehensive and open-source serverless function-as-a-service framework for quantum computing.
- Support developing quantum functions using 4 popular SDKs, including Qiskit, Q#, Cirq, and Braket.
- Built-in APIs with API gateway to manage system components, quantum functions, jobs, quantum backend and providers.
- Simplify quantum programming and enable hybrid quantum-classical function development.
- Execute quantum functions on both internal quantum simulators and external quantum computers/simulators, such as IBM Quantum and Strangeworks platforms.

- **Project's Github**: https://github.com/Cloudslab/qfaas

- **More information:** iQuantum Initiative (CLOUDS Lab) – Publication – Author's website.
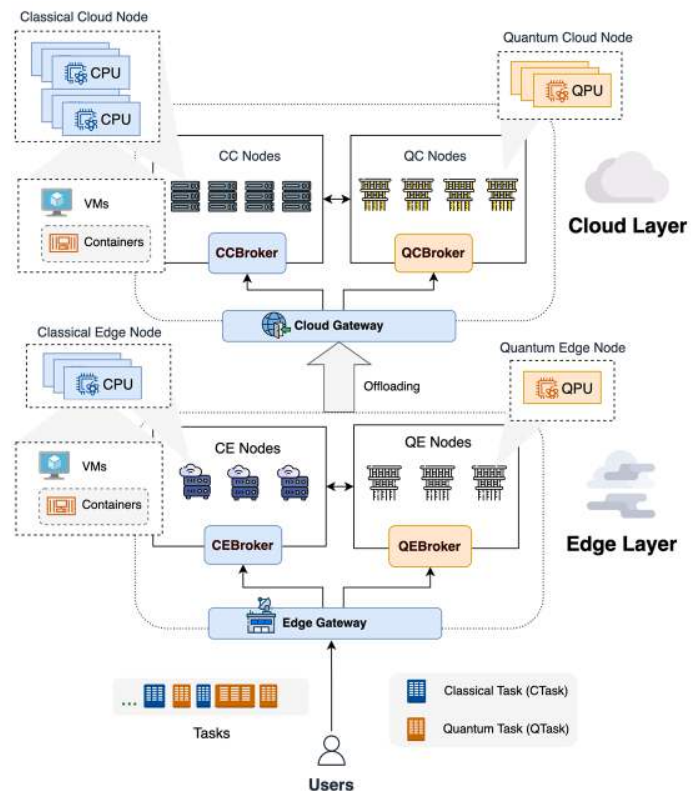
Reference

[1] Hoa T. Nguyen, Muhammad Usman, and Rajkumar Buyya, "*QFaaS: A Serverless Function-as-a-Service framework for Quantum computing*," Future Generation Computer Systems, vol. 154. Elsevier BV, pp. 281–300, May 2024. doi: 10.1016/j.future.2024.01.018

iQuantum - A Toolkit for Modeling and Simulation of Quantum Computing Environments

As quantum computers become increasingly accessible through cloud services and potentially extend to edge networks in the future, the demand for efficient resource management strategies is paramount to ensure the efficient utilization of quantum computing resources. However, the limitations of employing practical quantum computing resources and the lack of quantum environment modeling toolkits have hindered the design and evaluation of quantum resource management policies. To address this challenge, we propose iQuantum, a lightweight and versatile discrete-event modeling and simulation toolkit (based on CloudSim) for quantum computing environments. iQuantum provides a set of quantum computing entities that can be customized and extended to support a wide range of different hybrid quantum computing environments, supporting research in quantum resource management (e.g., task scheduling, backend selection, hybrid task orchestration), designing and prototyping of quantum computing systems.

Highlights

- Modeling quantum computing entities: QDatacenters, QNode, QPU, QTask, and QBroker.

- Modeling and simulation of quantum resource management, task scheduling, and backend selection policies for quantum computing environments.

- Modeling Hybrid Quantum-Classical Task Orchestration and Offloading in the Cloud-Edge Continuum.

- Importing quantum nodes and workload dataset (from calibration data and QASM files) and exporting simulation results.

- **Project's Github**:
  https://github.com/Cloudslab/iQuantum

- **Reference**

[1] Hoa T. Nguyen, Muhammad Usman, and Rajkumar Buyya, *"iQuantum: A Case for Modeling and Simulation of Quantum Computing Environments," 2023 IEEE International Conference on Quantum Software (QSW)*, Chicago, IL, USA, 2023, pp. 21-30, doi: 10.1109/QSW59989.2023.00013.

[2] Hoa T. Nguyen, Muhammad Usman, and Rajkumar Buyya, *"iQuantum: A Toolkit for Modeling and Simulation of Quantum Computing Environments"*, Journal of Software: Practice and Experience, Wiley, 2024.

9. Moments with Visitors, Colleagues and International Hosts

8th International Conference on Emerging Applications of Information Technology (EAIT 2024), Kolkata, India, January 12-13, 2024.

A snap with UniMelb students, Distributed Systems, Semester 1, 2024.

International Symposium on Cloud, Quantum Computing, and AI Applications, Bidar, India, July 1-3, 2024.

IEEE International Conference on Cloud Computing (CLOUD 2024), ShenZhen, China, July 7-13, 2024.

Chinese Academy of Science, Shenzhen, China, Dec. 4, 2024.

Macao Symposium on Cloud Computing and Intelligent Driving (CCID 2024), Macau, China, December 6-7, 2024.

17th IEEE/ACM International Conference on Utility and Cloud Computing (UCC 2024), Dubai, UAE

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A Seminar at G.Pulla Reddy College of Engineering, Kurnool, Dec. 21, 2024.