Mushu Li

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RESEARCH INTERESTS

Mobile Edge Computing
Computation offloading for unmanned autonomous systems
Edge-fog-cloud computing resource orchestration

Intelligent Internet-of-Things
Artificial intelligence based network modeling, protocol design, and resource management in IoT
Network resource management for connected vehicles

6G Wireless Communication Networks
Edge intelligence in radio access networks
Network virtualization and slicing for 6G
Adaptive video streaming in mobile virtual reality applications

EMPLOYMENT

Post-doctoral Fellow   **June 2022 - Present**
Department of Electrical, Computer, & Biomedical Engineering
Toronto Metropolitan University, Toronto, Ontario, Canada
Supervisor: Professor Lian Zhao

Post-doctoral Fellow   **Sept. 2021 - June, 2022**
Department of Electrical and Computer Engineering
University of Waterloo, Waterloo, Ontario, Canada
Supervisor: Professor Xuemin (Sherman) Shen

EDUCATION

Doctor of Philosophy, Electrical and Computer Engineering   **Sept. 2017 - Aug. 2021**
University of Waterloo, Waterloo, Ontario, Canada
Supervisor: Professor Xuemin (Sherman) Shen
GPA: 89.5/100
Thesis Title: Computation Offloading and Task Scheduling on Network Edge

Master of Applied Science, Electrical Engineering   **Sept. 2015 - Aug. 2017**
Ryerson University, Toronto, Ontario, Canada
Supervisor: Professor Lian Zhao
GPA: 98/100
Thesis Title: Load Balancing for Smart Grid: Centralized and Distributed Approaches

Bachelor of Engineering (Honours), Electrical Engineering   **Sept. 2011 - Aug. 2015**
University of Ontario Institute of Technology, Oshawa, Ontario, Canada
GPA: 89/100
Graduate with Highest Distinction

Capstone Project: DC Power-Line Communication Network for Automotive Applications

RESEARCH EXPERIENCE

All my previous research contributions are centered at **mobile edge computing** and **network resource management**. My long-term research plan is to integrate **machine learning techniques** into **resource management for next-generation communication networks**. The integration involves data-driven network modeling, intelligent network protocol design, and automated resource provisioning for highly diversified services. My research experience is briefly summarized below.

Postdoctoral Research Fellow   **Sept. 2021 - Present**

Broadband Communication Research (BBCR) Laboratory
Department of Electrical and Computer Engineering
University of Waterloo, Canada

- **Holistic Network Virtualization for 6G**
    - Network resource virtualization and management for emerging network applications in 6G
    - Digital twin-driven network management and data analysis

- **Ubiquitous Intelligence in 6G**
    - Resource provisioning for supporting artificial intelligence (AI) applications in wireless networks
    - AI-assisted network virtualization and slicing
    - Network optimization for edge intelligence and distributed learning in radio access networks

Research Assistant   **Sept. 2017 - Aug. 2021**

Broadband Communication Research (BBCR) Laboratory
Department of Electrical and Computer Engineering
University of Waterloo, Canada

- **Machine Learning for Next-Generation Wireless Communication Networks**
    - Machine learning assisted automated radio access network slicing and network management
    - Learning based joint computing, caching, and communication resource orchestration
    - Deep reinforcement learning for improving performance of heterogeneous wireless communications

- **Mobile Edge Computing in Internet of Vehicles**
    - Model-based and model-free optimal computation task assignments in vehicular networks
    - Vehicle-to-infrastructure communications assisted computation task offloading and migration
    - Age-aware computation scheduling for edge-assisted autonomous driving applications
    - Joint computation resource allocation and trajectory design for unmanned aerial vehicle based wireless networks

- **Electric Vehicle Energy Allocation in Smart Grids**
    - Electric vehicle charging scheduling in complex and large-scale transportation networks
    - Power flow optimization subject to electric vehicle charging constraints
    - Funded in part by the Natural Sciences and Engineering Research Council of Canada (NSERC) under Grant STPGP493787

Research Assistant   **Sept. 2015 - Aug. 2017**

Department of Electrical, Computer and Biomedical Engineering
Ryerson University, Canada

- **Communication Resource Management for Vehicular Networks**
  - Novel general framework development for spectrum allocation in cognitive radio enabled vehicular networks
  - Model-free optimization and proactive resource allocation for high-mobile mobile users

- **Elastic Power Loads Scheduling in Smart Grids**
  - Data analysis of daily energy usages for residential, industrial and commercial units
  - Power system reliability improvement by elastic power load scheduling

Research Assistant   **Sept. 2014 - Apr. 2015**
Department of Electrical Engineering
University of Ontario Institute of Technology, Canada
- **DC Powerline Communication Network for Automotive Applications**
  - Power-line communication network deployment for vehicle communication bus
  - Achieved 1st. place at the Technical Paper and Design Project Competition in ICUE 2015 and 1st. place at UOIT Electrical and Software Engineering Capstone Project Competition in 2015.

FUNDING EXPERIENCE

[F1] Holistic Wireless Network Virtualization: Digital and Intelligent Transformation
Towards 6G   2022—2024
Natural Sciences and Engineering Research Council of Canada (NSERC)
Prestigious post-doctoral funding in Canada
PI: Mushu Li - CAD $90,000 over 2 years

[F2] Efficient Charging Solutions for PHEVs in Intelligent Transportation System   2018—2021
Natural Sciences and Engineering Research Council of Canada (NSERC)
Prestigious doctoral funding in Canada
PI: Mushu Li - CAD $105,000 over 3 years

[F3] Water-filling Solution for Demand Side Management in Smart Grids   2016—2017
Ontario Graduate Scholarship (OGS) Program
PI: Mushu Li - CAD $15,000 over 1 year

[F4] Powerline Communication Network for Automotive Applications   2015—2016
Ontario Graduate Scholarship (OGS) Program
PI: Mushu Li - CAD $15,000 over 1 year

HONORS and AWARDS

- NSERC Postdoctoral Fellowship (PDF) Award   2022—2024
  - Above 80th percentile standing out of all applications in Selection Committee for Electrical Engineering
- University Finalist for the Alumni Gold Medal   2021
- NSERC Canada Graduate Scholarships - Doctoral   2018—2021
  - 284 recipients out of 1687 applications (16% success rate)
  - Ranking: 6 out of 67 applications in scholarship selection committee for electrical engineering
- President's Graduate Scholarship, University of Waterloo   2018—2021
- Faculty of Engineering Awards for Winter 2021, University of Waterloo   2021
- Jon W. Mark Graduate Scholarship in Communication, University of Waterloo   2020
- Faculty of Engineering Awards for Spring 2020, University of Waterloo   2020
- Faculty of Engineering Awards for Winter 2020, University of Waterloo   2020

- Faculty of Engineering Awards for Fall 2018, University of Waterloo   2019
- Graduate Research Studentship, University of Waterloo   2017
- Faculty of Engineering Domestic Doctoral Student Award, University of Waterloo   2017
- Provost Doctoral Entrance Award for Women, University of Waterloo   2017
- Master Thesis Nominated for "Governor General's Gold Medal", Ryerson University   2017
- Ontario Graduate Scholarships   2016—2017
- ECE Graduate Research Excellence Award, Ryerson University   2017
- Ontario Graduate Scholarships   2015—2016
- Aditya Jha Diversity Award, Ryerson University   2016
- Technical Paper and Design Project Competition in ICUE, University of Toronto   2015
    - Ranking: 1-st place out of 23 design projects
- Scotiabank Group Award, University of Ontario Institute of Technology   2014
- President's List, University of Ontario Institute of Technology (5 times)   2011—2015
- Dean's List, University of Ontario Institute of Technology (2 times)   2011—2015

PUBLICATIONS

Book & Book Chapters

[B1]   J. Gao, **M. Li**, and W. Zhuang, "Connectivity and Edge Computing in IoT: Customized Designs and AI-based Solutions," Springer International Publishing, ISBN-10: 3030887421, ISBN-13: 9783030887421, 168 pages, 2021.

[B2]   J. Gao, **M. Li**, X. Lin, and L. Zhao, "State Transition Field: A New Framework for Mobile Dynamic Caching", in "Broadband Communications, Computing, and Control for Ubiquitous Intelligence", 2021.

Refereed Journal Papers – Published, Accepted, or With Decisions

[J1]   **M. Li**, J. Gao, C. Zhou, X. Shen, and W. Zhuang "Slicing-Based Artificial Intelligence Service Provisioning on the Network Edge: Balancing AI Service Performance and Resource Consumption of Data Management,"
IEEE Vehicular Technology Magazine, Accepted, 8 two-column pages, 2021.

[J2]   X. Shen, J. Gao, W. Wu, **M. Li**, C. Zhou, and W. Zhuang "Holistic Network Virtualization and Pervasive Network Intelligence for 6G,"
IEEE Communications Surveys and Tutorials, Accepted, 22 two-column pages, 2021.

[J3]   W. Wu, C. Zhou, **M. Li**, H. Wu, H. Zhou, N. Zhang, X. Shen, and W. Zhuang "AI-Native Network Slicing for 6G Networks,"
IEEE Wireless Communication, Accepted, 8 two-column pages, 2021.

[J4]   W. Wu, N. Chen, C. Zhou, **M. Li**, X. Shen, W. Zhuang, X. Li, "Dynamic RAN Slicing for Service-Oriented Vehicular Networks via Constrained Learning,"
IEEE Journal on Selected Areas in Communications, vol. 39, no. 7, pp. 2076-2089, July 2021.

[J5]   **M. Li**, J. Gao, L. Zhao, and X. Shen, "Adaptive Computing Scheduling for Edge-assisted Autonomous Driving,"
IEEE Transactions on Vehicular Technology, vol. 70, no. 6, pp. 5318-5331, June 2021.

[J6]   J. Gao, W. Zhuang, **M. Li**, X. Shen and X. Li, "MAC for Machine Type Communications in Industrial IoT – Part I: Protocol Design and Analysis,"
IEEE Internet of Things Journal, vol. 8, no. 12, pp. 9945-9957, June 2021.

[J7] J. Gao, W. Zhuang, **M. Li**, X. Shen and X. Li, "MAC for Machine Type Communications in Industrial IoT – Part II: Scheduling and Numerical Results,"
IEEE Internet of Things Journal, vol. 8, no. 12, pp. 9958-9969, June 2021.

[J8] H. Liang, X. Zhang, X. Hong, Z. Zhang, **M. Li**, G. Hu, and F. Hou, "Reinforcement Learning Enabled Dynamic Resource Allocation in the Internet of Vehicles,"
IEEE Transactions on Industrial Informatics, vol. 17, no. 7, pp. 4957-4967, July 2021.

[J9] **M. Li**, J. Gao, L. Zhao, and X. Shen, "Deep Reinforcement Learning for Collaborative Edge Computing in Vehicular Networks,"
IEEE Transactions on Cognitive Communications and Networking, vol. 6, no. 4, pp. 1122-1135, Dec. 2020.

[J10] F. Wang, J. Gao, **M. Li** and L. Zhao, "Autonomous PEV Charging Scheduling Using Dyna-Q Reinforcement Learning,"
IEEE Transactions on Vehicular Technology, vol. 69, no. 11, pp. 12609-12620, Nov. 2020.

[J11] **M. Li**, N. Cheng, J. Gao, Y. Wang, L. Zhao and X. Shen, "Energy-Efficient UAV-Assisted Mobile Edge Computing: Resource Allocation and Trajectory Optimization,"
IEEE Transactions on Vehicular Technology, vol. 69, no. 3, pp. 3424-3438, Mar. 2020. (**Popular Article, Cited: 120**)

[J12] **M. Li**, J. Gao, N. Chen, L. Zhao, and X. Shen, "Decentralized PEV Power Allocation with Power Distribution and Transportation Constraints,"
IEEE Journal on Selected Areas in Communications, vol. 38, no.1, pp. 229-243, Jan. 2020.

[J13] X. Shen, J. Gao, W. Wu, K. Lyu, **M. Li**, W. Zhuang, X. Li, J. Rao, "AI-Assisted Network-Slicing Based Next-Generation Wireless Networks,"
IEEE Open Journal of Vehicular Technology, vol. 1, pp. 45-66, Jan. 2020. (**Popular Article, Cited: 110**)

[J14] N. Chen, J. Ma, **M. Li**, M. Wang and X. Shen, "Energy Management Framework for Mobile Vehicular Electric Storage,"
IEEE Network, vol. 33, no. 6, pp. 148-155, Nov.-Dec. 2019.

[J15] J. Gao, **M. Li**, L. Zhao and X. Shen, "Contention Intensity Based Distributed Coordination for V2V Safety Message Broadcast,"
IEEE Transactions on Vehicular Technology, vol. 67, no. 12, pp. 12288-12301, Dec. 2018.

[J16] **M. Li**, L. Zhao and H. Liang, "An SMDP-Based Prioritized Channel Allocation Scheme in Cognitive Enabled Vehicular Ad Hoc Networks,"
IEEE Transactions on Vehicular Technology, vol. 66, no. 9, pp. 7925-7933, Sept. 2017.

[J17] **M. Li**, P. He and L. Zhao, "Dynamic Load Balancing Applying Water-Filling Approach in Smart Grid Systems,"
IEEE Internet of Things Journal, vol. 4, no. 1, pp. 247-257, Feb. 2017.

[J18] P. He, **M. Li**, L. Zhao, B. Venkatesh and H. Li, "Water-Filling Exact Solutions for Load Balancing of Smart Power Grid Systems,"
IEEE Transactions on Smart Grid, vol. 9, no. 2, pp. 1397-1407, Mar. 2018.

Conference Papers

[C1] N. Chen, **M. Li**, M. Wang, Z. Su, J. Li, and X. Shen, "A Dynamic Pricing Based Scheduling Scheme for Electric Vehicles as Mobile Energy Storages,"
IEEE International Conference on Communications (ICC), virtual/Montreal, Canada, June 2021.

[C2] **M. Li**, J. Gao, N. Zhang, L. Zhao and X. Shen, "Collaborative Computing in Vehicular Networks: A Deep Reinforcement Learning Approach,"
IEEE International Conference on Communications (ICC), virtual/Dublin, Ireland, June 2020.

[C3] N. Chen, **M. Li**, M. Wang, J. Ma, and X. Shen, "Compensation of Charging Station Overload via On-road Mobile Energy Storage Scheduling,"
IEEE Global Communications Conference (GLOBECOM), Hawaii, USA, Dec. 2019.

[C4] **M. Li**, J. Gao, L. Zhao and X. Shen, "Task Time Allocation and Reward Scheme for PEV Charging Station Advertising,"
IEEE International Conference on Communications (ICC), Shanghai, China, June 2019.

[C5] **M. Li** and L. Zhao, "A Decentralized Load Balancing Approach for Neighbouring Charging Stations via EV Fleets,"
IEEE Vehicular Technology Conference (VTC-Fall), Toronto, Canada, Sept. 2017.

[C6] J. Gao, **M. Li**, P. He, and L. Zhao, "Incentive for Distributed Optimization in Multi-User Network: A Study of Two Scenarios,"
IEEE Vehicular Technology Conference (VTC-Fall), Toronto, Canada, Sept. 2017.

[C7] M. Baljon, **M. Li**, H. Liang, and L. Zhao, "SMDP-Based Resource Allocation for Wireless Networks with Energy Harvesting Constraints,"
IEEE Vehicular Technology Conference (VTC-Fall), Toronto, Canada, Sept. 2017.

[C8] L. Ferdouse, **M. Li**, L. Guan and A. Anpalagan, "Bayesian Workload Scheduling in Multimedia Cloud Networks,"
IEEE International Workshop on Computer Aided Modelling and Design of Communication Links and Networks (CAMAD), Toronto, Canada, Oct. 2016.

[C9] **M. Li**, P. He and L. Zhao, "Dynamic Elastic Load Scheduling Achieving Load Balancing for Smart Grid,"
IEEE/CIC International Conference on Communications in China (ICCC), Chengdu, China, July 2016.

TEACHING EXPERIENCE

Sessional Lecturer   **May 2022 - Aug. 2022**
Department of Electrical and Computer Engineering, University of Waterloo
Undergraduate/Graduate course: **ECE 414, ECE 614 - Wireless Communications**

Teaching Assistant   **May 2021 - Aug. 2021**
Department of Electrical and Computer Engineering, University of Waterloo
Undergraduate/Graduate course: **ECE 414, ECE 614 - Wireless Communications**
The responsibility of the teaching assistantship includes:
   - Providing tutorial sessions every week for undergraduate and graduate students
   - Holding office hours to answer questions from students in both courses
   - Grading homework assignments and quizzes
   - Grading final exam for ECE 414 and project report for ECE 614
My responsibility also includes: recoding tutorial videos; adopting inquiry-based and cooperative learning methods to facilitate students' understanding on course materials; responding to students' questions via emails. I received an outstanding rating on the teaching assistantship survey, particularly for my knowledge of course material, the availability, and the approachability during the teaching assistantship

Teaching Assistant   **Sept. 2018 - Dec. 2018**
Department of Electrical and Computer Engineering, University of Waterloo
Undergraduate course: **ECE 318 - Analog and Digital Communication**
The responsibility of the teaching assistantship includes: facilitating laboratory sessions and offering tutorial session for over 140 undergraduate students; holding office hours for lecture and laboratory questions; proctoring and grading midterm and final exams

Teaching Assistant   **Jan. 2018 - Apr. 2018**
Department of Electrical and Computer Engineering, University of Waterloo
Undergraduate course: **ECE 318 - Analog and Digital Communication**
The responsibility of the teaching assistantship includes: facilitating laboratory sessions; offering tutorial session for over 180 undergraduate students; holding office hours for lecture and laboratory questions; proctoring and grading midterm and final exams

Certificate of ExpecTAtions Teaching Assistant Training Workshop   **Dec. 2018**
Department of Electrical and Computer Engineering, University of Waterloo
ExpecTAtion workshop prepares graduate students for a teaching assistantship, which consists of:
- Two group lectures on general TA responsibility
- One consultant session on ECE department course
- A marking exercise under the guidance of two departmental mentors

Teaching Assistant   **Sept. 2015 - Apr. 2017**
Department of Electrical, Computer and Biomedical Engineering, Ryerson University
Undergraduate course: **ELE635 - Communication Systems**
                             ELE404 - Electronic Circuits I
                             EES508 - Digital Systems
                             EES512 - Electric Circuits
                             ELE745 - Digital Communications
Over 400 contract hours are involved in the teaching assistantships, and the responsibility includes: facilitating laboratory sessions; offering tutorial session for undergraduate students; holding office hours for lecture and laboratory questions; proctoring and grading midterm and final exams

SELECTED SEMINARS AND PRESENTATIONS

[P1] Holistic Network Virtualization and Intelligence
      UW & Huawei Workshop, Department of Electrical and Computer Engineering, University of Waterloo, Nov. 2021.

[P2] Computation Offloading and Task Scheduling on Network Edge
      ECE PhD Seminar, University of Waterloo, July 2021.

[P3] Computation Offloading and Task Scheduling on Network Edge
      Research Seminar, Broadband Communications Research Lab, University of Waterloo, July 2021.

[P4] Adaptive Computing Scheduling for Edge-assisted Autonomous Driving
      Research Seminar, Broadband Communications Research Lab, University of Waterloo, Sept. 2020.

[P5] Collaborative Computing in Vehicular Networks: A Deep Reinforcement Learning Approach
      IEEE International Conference on Communications (ICC), virtual conference, June 2020.

[P6] Collaborative Computing in Vehicular Networks: A Deep Reinforcement Learning Approach
      Research Seminar, Broadband Communications Research Lab, University of Waterloo, Oct. 2019.

[P7] Load Balancing for Smart Grid: Centralized and Distributed Approaches
      Research Seminar, Broadband Communications Research Lab, University of Waterloo, Jan. 2018.

[P8] Load Balancing for Smart Grid: Centralized and Distributed Approaches
      Graduate Research Seminar, Department of Electrical and Computer Engineering, University of Waterloo, Nov. 2017.

[P9] A Decentralized Load Balancing Approach for Neighbouring Charging Stations via EV Fleets
      IEEE Vehicular Technology Conference (VTC-Fall), Toronto, Canada, Sept. 2017

PROFESSIONAL SERVICES

Technical Program Committee Membership
- IEEE International Conference on Computer Communications (INFOCOM), Virtual, May 2022
- IEEE International Conference on Communications (ICC), Virtual, June 2022
- EAI CollaborateCom, Suzhou, China, Oct. 2021
- IEEE Vehicular Technology Conference (VTC-Fall), Virtual, Nov. 2021
- IEEE Vehicular Technology Conference (VTC-Fall), Victoria, Canada, Nov. 2020
- EAI CollaborateCom, Virtual, Oct. 2020

Reviewer of Refereed Journals
- IEEE Internet of Things Journal
- IEEE Transactions on Wireless Communications
- IEEE Transactions on Vehicular Technology
- IEEE Communication Letters
- IEEE Transactions on Cognitive Communications and Networking
- IEEE Network Magazine
- IEEE Communication Standard Magazine
- Wireless Communication and Mobile Computing
- Journal of Systems Architecture
- Wireless Networks
- Transactions on Emerging Telecommunications Technologies
- ETRI Journal
- Journal of Communications and Information Networks
- Peer-to-Peer Networking and Application

Reviewer of Selected Conference
- IEEE Vehicular Technology Conference (VTC-Fall), Virtual, Nov. 2021
- IEEE International Conference on Communications (ICC), Montreal, Canada, June 2021
- IEEE Global Communications Conference (GLOBECOM), Taibei, Taiwan, Dec. 2020
- IEEE Vehicular Technology Conference (VTC-Fall), Victoria, Canada, Nov. 2020
- IEEE International Conference on Communications (ICC), Dublin, Ireland, June 2020
- IEEE Vehicular Technology Conference (VTC-Spring), Antwerp, Belgium, May 2020
- International Conference on Computing, Networking and Communications (ICNC), Hawaii, USA, Feb. 2020
- IEEE Global Communications Conference (GLOBECOM), Abu Dhabi, UAE, Dec. 2019
- IEEE Vehicular Technology Conference (VTC-Fall), Hawaii, USA, Nov. 2019
- IEEE International Conference on Communications (ICC), Shanghai, China, June 2019
- IEEE International Conference on Green Computing and Communications, Halifax, Canada, July 2018

Volunteer
– 2017 IEEE 86th Vehicular Technology Conference (VTC2017-Fall), Toronto, Canada, Oct. 2017

Group Coordinator, BBCR AI Research Group (7 members)   Sept. 2021—Present
Project: Proactive User-centric Networking for Next Generation Wireless Communications
Duties: Organizing group members to do advanced research, developing technologies for next generation wireless networks, discussing research ideas with group members, discussing with the researchers of industrial partner, Huawei, Canada about the project progress, organizing biweekly group meetings and backup meeting files, and collecting meeting notes and writing minutes.

Group Coordinator, BBCR Digital Twin Research Group (4 members) Sept. 2021—Present
Duties: Organizing group members to do advanced research, developing technologies for digital twin-assisted network virtualization, discussing research ideas with group members, discussing with the researchers of

industrial partner, organizing weekly group meetings and backup meeting files, and collecting meeting notes and writing minutes.

ECE Graduate Research Seminar (GRS) Organizing Team **Jan. 2018 - May 2021**

ECE GRS holds a series of research seminars each term at University of Waterloo. I joined the organizing team in Jan. 2018, and my main responsibilities include:

- Invite all ECE graduate students to provide research talks and tutorials
- Organize and host the seminars
- Participate in selecting "Best Speaker" award of GRS
- **Over 30 seminars have been organized and hosted**