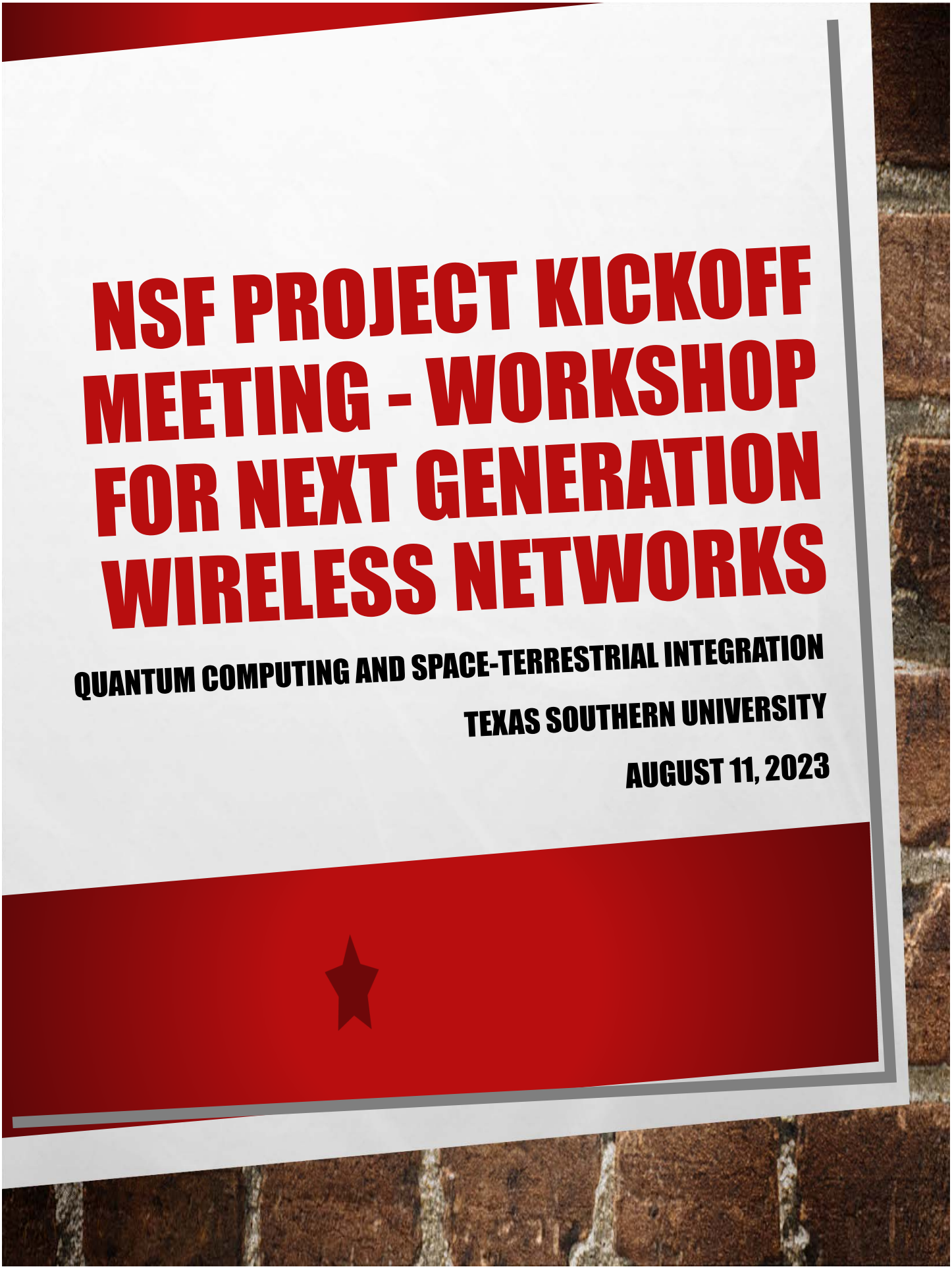
# NSF PROJECT KICKOFF MEETING - WORKSHOP FOR NEXT GENERATION WIRELESS NETWORKS

## QUANTUM COMPUTING AND SPACE-TERRESTRIAL INTEGRATION

TEXAS SOUTHERN UNIVERSITY

AUGUST 11, 2023



# TECHNICAL PROGRAM OVERVIEW

TECH Building Conference Room 316

Texas Southern University

Zoom Meeting Link

August 11, 2023

- 10:00-10:15: **Introduction**
- 10:15-11:00: **Variational Quantum Pulse Learning**
  Dr. Yiyu Shi, the University of Notre Dame
- 11:15-12:00: **Quantum Technologies for Secure Communications in Space**
  Dr. Angeles Vazquez Castro, Universitat Autonoma De Barcelona
- 12:15-13:00: Workshop Lunch
- 13:00-13:45: **Quantum Optimization for 6G**
  Dr. Zhu Han, the University of Houston
- 14:00-14:45: **Privacy Preserving, Efficient, and Scalable Edge Computing for NextG WN**
  Dr. Lijun Qian, Prairie View A&M University
- 15:00-17:00: **Research Capacity and Partnerships Building in Next-Generation Communication Ecosystems with Vertical Intelligence (NSF Award)**
  Dr. Xiangfang Li (PVAMU) --- Overview
  Dr. Zhu Han (UH) --- Research Thrusts.
  Dr. Wei Li (TSU) --- Uncertainty Research Methodology
  Dr. Pamela Obiomon (PVAMU) --- Education and Outreach

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# VARIATIONAL QUANTUM PULSE LEARN

Dr. Yiyu Shi, the University of Notre Dame

**ABSTRACT**: Quantum computing is among the most promising emerging techniques to solve problems that are computationally intractable on classical hardware. A large body of existing works focus on using variational quantum algorithms on the gate level for machine learning tasks, such as the variational quantum circuit (VQC). However, VQC has limited flexibility and expressibility due to limited number of parameters, e.g. only one parameter can be trained in one rotation gate. On the other hand, we observe that quantum pulses are lower than quantum gates in the stack of quantum computing and offers more control parameters. Inspired by the promising performance of VQC, in this talk we present variational quantum pulses (VQP), A novel paradigm to directly train quantum pulses for learning tasks. The proposed method manipulates variational quantum pulses by pulling and pushing the amplitudes of pulses in an optimization framework. Similar to variational quantum algorithms, our framework to train pulses maintains the robustness to noise on noisy intermediate-scale quantum (NISQ) computers. In an example task of binary classification, VQP learning achieves up to 11% and 9% higher accuracy compared with VQC learning on the QISKIT noise simulators (with noise model from real machine) and IBMQ-JARKATA, respectively, demonstrating its effectiveness and feasibility. Stability for VQP to obtain reliable results has also been verified in the presence of noise.

**BIO**: Dr. Yiyu Shi is currently a professor in the Department of Computer Science and Engineering at the University of Notre Dame, the site Director of National Science Foundation I/UCRC Alternative and Sustainable Intelligent Computing, and the Director of the Sustainable Computing Lab (SCL). He received his B.S. In Electronic Engineering from Tsinghua University, Beijing, in 2005, the M.S and Ph.D. Degree in Electrical Engineering from the University of California, Los Angeles, in 2007 and 2009, respectively. His current research interests focus on hardware intelligence on emerging platforms. In recognition of his research, more than a dozen of his papers have been nominated for or awarded as the best paper in top Journals and Conferences, including the 2021 IEEE Transactions on Computer-Aided Design Donald O Pederson Best Paper Award. He is also the recipient of Facebook Research Award, IBM Invention Achievement Award, Japan Society for the Promotion of Science (JSPS) Faculty Invitation Fellowship, Humboldt Research Fellowship, IEEE ST. Louis Section Outstanding Educator Award, Academy of Science (ST. Louis) Innovation Award, Missouri S&T Faculty Excellence Award, NSF CAREER Award, IEEE Region 5 Outstanding Individual Achievement Award, the Air Force Summer Faculty Fellowship, and IEEE Computer Society Mid-career Research Achievement Award. He has served on the technical program committee of many international conferences. He is the deputy Editor-In-Chief of IEEE VLSI CAS Newsletter, and an Associate Editor of various IEEE and ACM Journals. He is an IEEE CEDA Distinguished Lecturer and an ACM Distinguished Speaker.


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# QUANTUM TECHNOLOGIES FOR SECURE COMMUNICATIONS IN SPACE

Dr. Angeles Vazquez Castro, Universitat Auonoma De Barcelona

**ABSTRACT**: In this talk, we first of all provide an overview of quantum resources, state-of-the art quantum technologies for communications and of the quantum initiatives around the world (with emphasis in Europe). Then, we present three space applications as identified in our recent project for the European space agency (ESA). The first one is Quantum-Enhanced Communications. In this case, we present potential gains (quantum advantage) and trade-offs for optical on/off keying (O3K) and binary phase shift keying (BPSK) communications. The second one is quantum physical layer cryptography, which realizes secure communication in space with quantum resources, cryptographic primitives and without the use of any key. We discuss the information theoretical security of this approach and its relation with the information theoretical security of quantum key distribution (QKD) and quantum secure direct communication (QSDC) protocols. Finally, we present the long-term application of entanglement-assisted classical capacity and discuss the effect of imperfect entanglement distribution.

**BIO:** Dr. Ángeles Vázquez-Castro received her Telecommunications Engineering Degree in 1994 and her Ph.D. (Cum Laude) in 1998, both from the Polytechnic University of Vigo, Spain. As a Post-Doctoral Fellow, She visited the University of Surrey, UK, University of Southern California, USA. She obtained a Research Fellowship from ESA in Noordwijk (the Netherlands) during 2002-2004. She has been an Associate Professor at the Autonomous University of Barcelona (Spain) since 2004, with part-time appointment at the University of Oslo (Norway) from 2008 to 2011. While at ESA, She was a founding member of the European Satellite Communications Experts Network (Satnex) wherein she carries out her ESA-funded research activities, contributing to standardization (ITU, ETSI, DVB, IRTF) and tutoring international PhDs. Her research has covered all layers of satellite communications while since 2016 her main research interest has been the design of (information theoretical) security protocols for space communications at physical and medium access layers. In her personal and research life she pursues her IKIGAI.

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# QUANTUM OPTIMIZATION FOR 6G

Dr. Zhu Han, the University of Houston

**ABSTRACT**: Benefited from the technology development of controlling Quantum particles and constructing Quantum hardware, Quantum Computation has attracted more and more attention in recent years. This talk will give an introduction of quantum computing and its applications in network optimization. We first introduce the basics of Quantum Computing and what quantum parallelism is. Second, we will discuss the adiabatic quantum computing math model and one real implementation, quadratic unconstrained binary optimization (QUBO) on d-wave quantum annealer. Then we propose a hybrid quantum benders' decomposition algorithm for joint quantum and classic CPU computing. Finally, we will discuss how our proposed framework can be employed in network optimization and machine learning in 6G.

**BIO**: Dr. Zhu Han received the B.S. Degree in Electronic Engineering from Tsinghua University, in 1997, and the M.S. and Ph.D. Degrees in Electrical and Computer Engineering from the University of Maryland, College Park, in 1999 and 2003, respectively. From 2000 to 2002, he was an R&D Engineer of JDSU, Germantown, Maryland. From 2003 to 2006, he was a Research Associate at the University of Maryland. From 2006 to 2008, he was an Assistant Professor at Boise State University, Idaho. Currently, he is a John and Rebecca Moores Professor in the Electrical and Computer Engineering Department as well as the Computer Science Department at the University of Houston, Texas. Dr. Han is an NSF CAREER award recipient of 2010, and the winner of the 2021 IEEE Kiyo Tomiyasu Award. He has been an IEEE Fellow since 2014, an AAAS Fellow since 2020, an IEEE Distinguished Lecturer from 2015 to 2018, and an ACM Distinguished Speaker from 2022-2025. Dr. Han is also a 1% highly cited researcher since 2017.

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# PRIVACY PRESERVING, EFFICIENT, AND SCALABLE EDGE COMPUTING FOR NEXTG WIRELESS NETWORKS

Dr. Lijun Qian, Prairie View A&M University

**ABSTRACT**: In order to extract knowledge from the large data collected by edge devices, traditional cloud based approach that requires raw data upload may not be feasible due to communication bandwidth limitation as well as privacy and security concerns of end users. To address these challenges, a novel privacy preserving edge computing framework is proposed in this study for image classification. Specifically, autoencoder will be trained unsupervised at each edge device individually, then the obtained latent vectors will be transmitted to the edge server for the training of a classifier. This framework would reduce the communications overhead and protect the data of the end users. Comparing to federated learning, the training of the classifier in the proposed framework does not subject to the constraints of the edge devices, and the autoencoder can be trained independently at each edge device without any server involvement. Furthermore, the privacy of the end users' data is protected by transmitting latent vectors without additional cost of encryption. Experimental results provide insights on the image classification performance vs. various design parameters such as the data compression ratio of the autoencoder and the model complexity. Potential implementation on the emerging analog AI chips will also be discussed

**BIO**: Dr. Lijun Qian is Texas A&M University System Regents Professor and AT&T Endowed Professor in the Department of Electrical and Computer Engineering at Prairie View A&M University (PVAMU). He is also the Director of the Center of Excellence in Research and Education for Big Military Data Intelligence (CREDIT Center). He received BE from Tsinghua University, MS from Technion-Israel Institute of Technology, and PhD from Rutgers University. Before joining PVAMU, he was with Bell-Labs Research in Murray Hill, New Jersey. He was a visiting professor of Aalto University, Finland. He led the team of students from the CREDIT Center to win the first place in the AI tracks at Sea challenge organized by the US Navy in 2021, and the first place in the IEEE CyberC Big Data Competition organized by the IEEE Big Data Initiative in October 2016. He received the Best Paper Award in IEEE RoboCom 2023 and IEEE Globecom 2017, the Central Bell-Labs Teamwork Award in 2003. His research interests are in the area of big data processing, artificial intelligence, quantum information science and quantum machine learning, wireless communications and mobile networks, network security and intrusion detection, and computational and systems biology.

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# RESEARCH CAPACITY AND PARTNERSHIPS BUILDING IN NEXT-GENERATION COMMUNICATION ECOSYSTEMS WITH VERTICAL INTELLIGENCE

## NSF AWARD 2302469 (2023-2026)

**PVAMU**: Xiangfang (Lindsey) Li, Ahmed Ahmed, Lijun Qian and Pamela Obiomon; **UH**: Zhu Han; **TSU**: Wei Li, Graham Thomas

### Research Capacity and Partnerships Building

- Next-Generation Wireless Communications (B5G/6G)
- Internet-of-Things (IoT) and Sensor Fusion
- Optimization and Game Theory
- Artificial Intelligence Machine Learning
- Network Science
- Data Analytics

- Build a pipeline to attract and recruit students especially African Americans in STEM
- Encourage and enable broad participation of HBCU/MSIs in advanced research
- Train HBCU faculty in advanced research and education (train the trainers)

### Research Thrusts

- **Thrust 1**: Optimized resource allocation in B5G/6G vertical wireless ecosystems
- **Thrust 2**: Hierarchical multi-resolution multimodal sensor fusion
- **Thrust 3**: Efficient privacy-preserving edge computing and federated learning

### Educational and Outreach Activities

- Curriculum Development
- Actively Recruiting Students
- Annual Tutorial Workshop
- Capstone Projects
- Internship program
- Research Mentorship
- Outreach to HBCU/MSIs
- Student Research Symposia

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