SC26 Network Research Exhibition: Demonstration Publishable Abstract

InterQnet: Heterogeneous Quantum Network Demonstrations at ARQNET

Joaquin Chung, Argonne National Laboratory, chungmiranda@anl.gov

Abstract

Quantum communications have evolved from theoretical constructs to metropolitan-scale demonstrations. As the field matures, it is poised to transform quantum computing, much like how classical networks reshaped classical computing. However, scalability remains a critical challenge, particularly in terms of platform diversity, node count, communication distance, and application scope. The InterQnet project pursues a two-pronged strategy to advance the state of the art in scalable quantum communications. In InterQnet-Achieve, we focus on practical realization of a heterogeneous quantum network by building and then integrating a prototype first-generation quantum repeater with an error mitigation scheme and a centralized automated network control system. In InterQnet-Scale, we focus on a systems study of architectural choices for scalable quantum networks by developing futuristic models of quantum network devices, advanced error correction schemes, and entanglement protocols. In this demonstration, we will showcase our progress towards the InterQnet-Achieve goals through prototypical systems for remote entanglement distribution between heterogeneous qubit platforms deployed across the Argonne Quantum Network Testbed (ArQNet).

Goals

In this demo, we demonstrate heterogeneous, photonic link establishment between microwave and atomic device platforms over several kilometers. A microwave-to-optical photon transducer coherently converts ~10 GHz microwave pulses to C-Band telecom-pulses for controlling an Erbium-doped photonic cavity. Additionally, we demonstrate progress toward Quantum Frequency Conversion (QFC) from 556 nm to 1520 nm of photonic qubits entangled with neutral atom qubits in the time-bin basis as well as distribution of frequency-converted photonic qubits over ArQNet. In particular, we demonstrate frequency conversion of single 556 nm photons with high efficiency and low added noise via anti-bunching correlation measurements locally at 556 nm and remotely at 1520 nm as well as preliminary results demonstrating emission of 556 nm photons entangled with the state of a neutral Yb atom trapped in an optical tweezer array.

Impacts

The path from small-scale demonstrations to national-scale, heterogeneous quantum networks remains blocked by challenges of scalability, control, and architectural clarity. Most existing efforts focus on homogeneous systems or simulations disconnected from experimental feedback. InterQnet distinguishes itself by: 1) integrating heterogeneous platforms, including atoms, ions, and superconducting qubits, in the first demonstrations of their kind, and 2) pursuing full-stack co-design, where protocols, control logic, and device models are developed in tandem to enable end-to-end system exploration. Through this combination of experimental integration and systems-level study, InterQnet is advancing toward building a full-stack heterogeneous quantum network (InterQnet-Achieve) and guiding the design of scalable architectures (InterQnet-Scale).

In particular, this photonic link demonstration represents a step towards the development of future heterogeneous quantum-computing systems that will require the transfer of quantum-state information between device platforms of vastly different frequencies.

Resources

This demonstration does not require any SCinet resources.

Involved Parties

- Joaquin Chung, Argonne National Laboratory, chungmiranda@anl.gov
- Joseph Petrullo, Argonne National Laboratory, jpetrullo@anl.gov
- Vasileios Niaouris, Argonne National Laboratory, vniaouris@anl.gov
- Robert Hayek, Argonne National Laboratory, rhayek@anl.gov
- Ely Eastman, Argonne National Laboratory, eeastman@anl.gov

- Zeyu Ye, Argonne National Laboratory, zeyu.ye@anl.gov
- Kara Hokenstad, Argonne National Laboratory, khokenstad@anl.gov
- Michael Bishof, Argonne National Laboratory, bishof@anl.gov
- Alan Dibos, Argonne National Laboratory, adibos@anl.gov
- Xu Han, Argonne National Laboratory, xu.han@anl.gov
- Rajkumar Kettimuthu, Argonne National Laboratory, kettimut@anl.gov