Quantum Technologies for UAS (QTech)

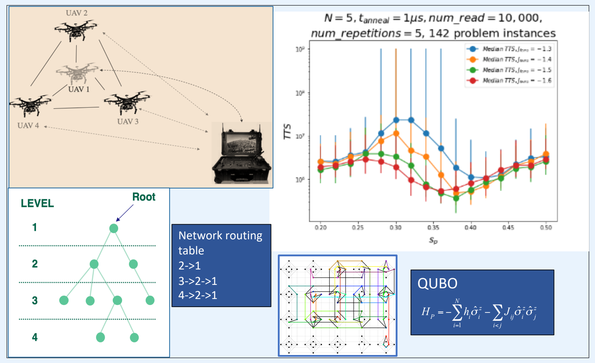
National Aeronautics and Space Administration

Overview/Description

Harness the power of quantum technologies to assure the availability of UAS communications against disruptions. Make use of quantum computing (e.g. quantum optimization) and quantum communication (e.g. quantum key distribution) to address the availability cybersecurity challenge. Our approach is three-fold: (1) Utilize quantum optimization algorithms to design robust network with routing redundancy that can respond adaptively to dynamically changing real-time environment and disruptions, (2) Utilize quantum optimization algorithms resource allocation for detection, localization, and tracking of mobile communication disruption agents, (3) Utilize quantum key distribution (QKD) to execute secure key sharing in high data rate optical communication and/or anti-jamming protocols for secure RF communication.

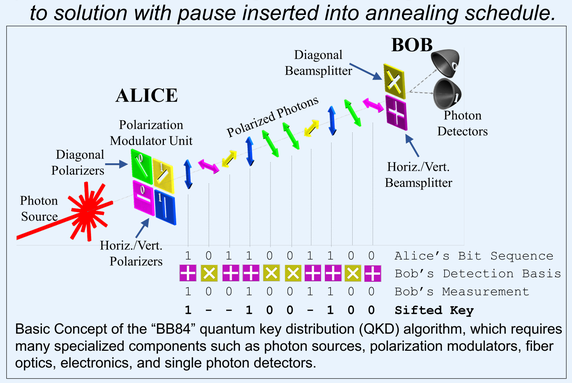
Feasibility Assessment / Benefit if Feasible

- Reliably solved 5-vehicle network robustness optimization problems: bounded-degree spanning-tree problems. Obtained 5x improvement by implementing intelligent annealing schedule. Integrated solutions with UAV demo. Demonstrates feasibility of quantum approaches to network robustness.
- Demonstrated feasibility of modulating and demodulating polarization states at high rates for quantum key distribution (QKD). Established a foundation secure free-space optical communications by allowing the secure exchange of encryption keys.
- Designed and implemented HPC approach for simulating quantum circuits. Used to establish frontier for quantum supremacy. Significance: we are entering the NISQ era with unprecedented ability to empirically test quantum algorithms



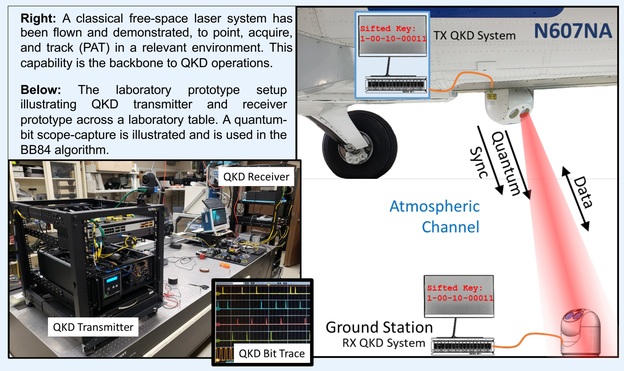
Robust communication network design: solved bounded degree spanning tree problems, with quantum annealer producing network routing table. Upper right: reduced time to solution with pause inserted into annealing schedule.

Demo based on UTM TCL4 Corpus Christi flight test. (Top) Aerial view with flight routes. (Bottom left) Key buildings in blue. (Bottom right) Demo area with model buildings.



Basic Concept of the "BB84" quantum key distribution (QKD) algorithm, which requires many specialized components such as photon sources, polarization modulators, fiber optics, electronics, and single photon detectors.

Basic concept of "BB84" quantum key distribution (QKD) protocol



Laboratory free-space QKD prototype (left) & UAS integration strategy (right)

Partners

- **Google,** NRSAA providing team with use of Google quantum processors, promising NASA HPC quantum circuit simulation,
- **Rigetti,** NRSAA for access to Rigetti's quantum processors
- **AFRL/RITE**, Collaboration for continued development of free-space optical communication (FSOC) terminals. Funding NASA Ames research on quantum algorithms and application benchmarking, including network robustness.
- **Univ. of Illinois**, Grant completed and investigate miniaturized QKD components
- **NASA UTM Project**, collaboration with respect to TCL Corpus Christi demo design to inform Qtech 'little Corpus Christi" demo space.

Recent Results / Status

- Supported Google's team in establishing quantum supremacy, a demonstration of one type of computation that can be done within minutes on their quantum processor which cannot be done in reasonable time on even the largest supercomputer.
- HPC circuit simulation code, qFlex, open sourced.
- QKD hardware has been developed into a system-level prototype. Testing and performance validations are in progress to validate the prototype QKD fiber optic strategy and algorithm.
- Classical free-space optical comm. system successfully completed a flight test, demonstrating pointing, acquisition, and tracking capability out to ranges greater than 50km.

Next Steps

- Finalize resource estimates for quantum approaches to robust network design on newly available partner quantum hardware.
- Complete 3-vehichle UAV demonstration, integrating solutions obtained from quantum hardware.
- Continue development of the QKD prototype and verify performance, towards the objective of evaluating feasibility of QKD integration with FSOC system for the NAS.
- Explore potential QTech transition to the Autonomous System subproject within ARMD's Transformational Tools and Technologies (TTT) Project. Avenue for providing communications availability and autonomy support for urban air mobility. Explore transition to AFRL effort to assess quantum technologies for AF aviation communication needs.

CONVERGENT AERONAUTICS SOLUTIONS