Orchestration of Entanglement Distribution over a Q-LAN using the IEQNET Controller

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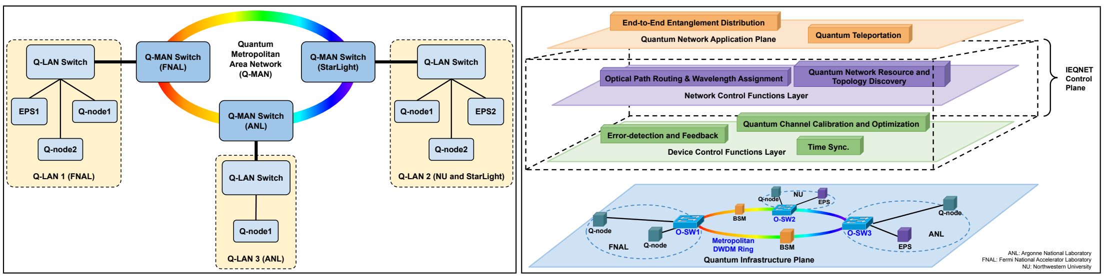
Abstract: We will demonstrate orchestration of entanglement distribution over a quantum local area network (Q-LAN) using a quantum network controller. Our controller enables multiple users to share a Q-LAN composed of commercial equipment for quantum communications.

1. Overview

The goal of the Illinois Express Quantum Network (IEQNET) project is to realize metropolitan-scale quantum networking using currently available technology. IEQNET consists of multiple sites in the greater Chicago area that are connected via dark fibers. These sites – which we call quantum local area networks (Q-LANs) – include the Fermi National Accelerator (Fermilab), Argonne National Laboratory, and Northwestern University. Furthermore, each Q-LAN has one or more quantum nodes (Q-Nodes) also connected via deployed fiber links on each site. Figure 1 shows IEQNET's logical topology and its three-plane architecture. The IEQNET architecture is described in detail in [1], where we present the design of a quantum network controller based on the principles of software-defined networking (SDN). In this demo we will present a prototype implementation of the IEQNET controller capable of orchestrating Q-Nodes deployed on the Argonne Q-LAN to provide entanglement distribution services to multiple users.



(a) (b)

Fig. 1. IEQNET's (a) logical topology and (b) its three-plane architecture [1].

2. Innovation

The field of quantum communications has taken two approaches in regards to quantum network architectures. From a top-down, futuristic view, researchers have proposed architectures for a global quantum internet [2, 3]. On the other hand, experimentalists and engineers have taken a bottom-up approach and demonstrated SDN-based systems for quantum key distribution (QDK) [4, 5]. The goal of IEQNET is to go beyond QKD and demonstrate quantum networking services such as entanglement distribution and teleportation [6, 7]. The innovation of this demo lays on enabling the interoperability between commercially available quantum communication devices (e.g., NuCrypt entangled photon sources, Quantum Opus single photon detectors, and Polatis all-optical SDN switches) via the IEQNET controller using standard network configuration protocols and interfaces (e.g., NETCONF).

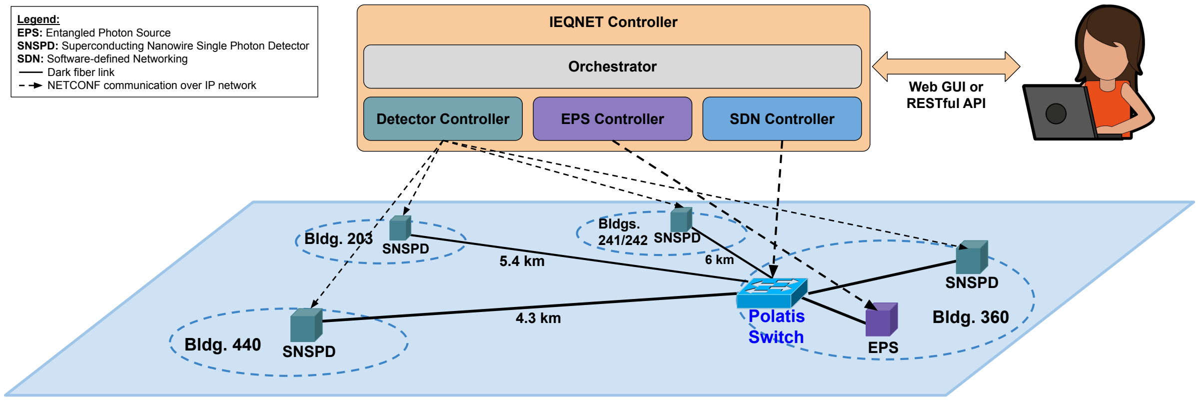


Fig. 2. Demo setup at the Argonne Q-LAN

3. OFC Relevance

OFC is the premier global event for optical communications and networking, and as such, it attracts a diverse audience composed of researchers and practitioners from both classical and quantum networking background. Moving quantum networks out of physics laboratories and into operational systems requires the exchange of ideas between physicists, (classical) network engineers, and computer scientists. We believe that showcasing our prototype of the IEQNET controller at OFC will spur a rich exchange of ideas and may initiate valuable collaborations.

4. Demo Content & Implementation

The objective of this demo is to show how users can request entanglement distribution between two Q-Nodes in a quantum network via the IEQNET controller. Figure 2 describes the proposed physical demo setup that will use the Argonne Q-LAN (part of IEQNET). Argonne's Q-LAN connects five buildings (buildings 203, 241, 242, 360, and 440) in the Argonne campus on a star topology using deployed fiber, although in the diagram in Fig. 2 we represent buildings 241 and 242 as a single node. Building 360 is the central node of the star and besides connecting all the stubs in the Q-LAN, it also hosts long distance dark fiber links to Fermilab (57 km) and StarLight (83 km). The central node is equipped with the following quantum communication devices:

- A NuCrypt entangled photon source (EPS) capable of generating entangled photons on the $|HH\rangle + |VV\rangle$ Bell state, generated using cascaded second harmonic generation spontaneous parametric down conversion (SHG-SPDC) in a Sagnac loop. The EPS operates on three pairs of wavelength channels with a pump laser centered at 1550.1 nm (ITU Ch. 34).
- A Polatis 16×16 SDN switch controlled via REST and NETCONF interfaces.
- A Quantum Opus superconducting nanowire single photon detector (SNSPD) system with two broadband detectors with 85% efficiency at 1550 nm wavelength.

Building 440 will be equipped with a six-detector Quantum Opus system, a pairs optimized for the O-band (1310 nm), another pair optimized for the C-band (1550 nm), and the last pair will be broadband. Buildings 203, 241, and 242 are still under commission, thus at the moment of the demo we will use them to create loops that will return to the central node's SNSPD, effectively creating fiber links with double the distance.

The IEQNET controller prototype is implemented in Python using an agent-based architecture. Local agents in the Q-Nodes (i.e., EPS and SNSPDs) use serial port communication to control the Q-Nodes using the commands defined by the manufacturers, while enabling a NETCONF server that the orchestrator communicates with. As mentioned before, the Polatis SDN switch already supports a NETCONF API. The orchestrator is deployed on a mini-server located in the central node. It implements NETCONF clients to issue commands to the Q-Node agents and SDN switch over a classical IP network. In the future, the IEQNET controller will include an SDN controller as a sub-system to control multiple SDN switches deployed on the other IEQNET sites (Fermilab and Northwestern University). To allow multiple users to schedule entanglement distribution requests, the IEQNET controller would implement a Web GUI or RESTful API.

The demo will be presented to attendees on a computer with VPN access to the IEQNET controller deployed in the mini-server at Argonne. The mini-server will be equipped with visualization tools that will show how entanglement distribution data is being collected in real time, and it will run post processing routines showing the results of entanglement distribution requests. Attendees will be able to interact with the IEQNET controller via the same computer we will use for the demo, making the session more engaging.

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