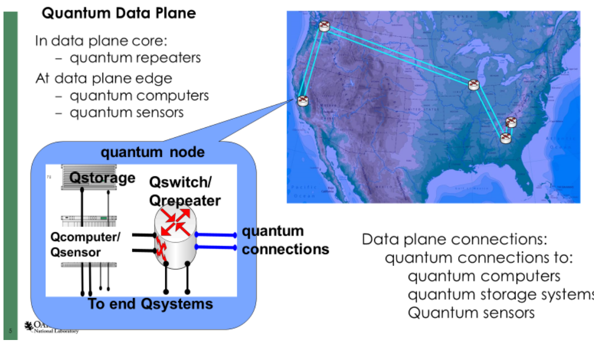
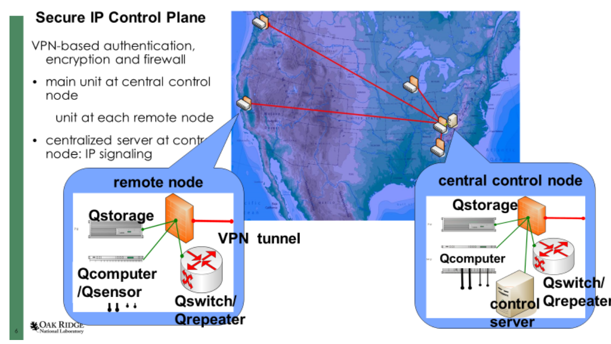
Continuous Test and Transition Infrastructure for Quantum Networking for Science Complex

Nicholas A. Peters and Nageswara S. Rao, Oak Ridge National Laboratory

Introduction: Quantum networking holds an enormous promise of unprecedented capabilities to DOE science federations in terms of secure communications, aggregating geographically separated quantum computers to realize larger ones, connecting quantum sensors at experimental facilities to remote computing and storage systems, and achieving quantum data transport. In the long term, quantum networks will be an integral part of DOE science federations that connect experiments with computations in mixed quantum and conventional modes. Currently, quantum network components technologies are under early development, for example, entanglement transfer distances are limited to few tens of miles over fiber links, no clear products are available for quantum repeaters, and there is limited ability to interface quantum sensors to transmission links. DOE's vision of connecting national facilities using a quantum internet requires connections spanning a few thousand miles. Currently the only way to transmit quantum information over 200 miles has been demonstrated using satellite communications. While this may be useful in the near term, as bandwidth requirements grow, such solution will prove too costly to scale. A more practical solution is to build a quantum internet to complement and leverage the conventional networks, in particular ESnet, and telecom fiber infrastructures.

Opportunity: The option of waiting until all quantum network components (including, links, repeaters and interconnects) are production ready will lead to inordinate delays and, testing them in isolation leaves their interoperability and integration into conventional network to be determined. We propose an approach to incubate and test these components in parallel at different sites inside their site enclaves, which are all embedded in a multi-site wide-area hybrid network ecosystem. The quantum components can be proactively developed inside this ecosystem and can be rolled into production as they mature.





Separate Data and Control Planes: We propose a network architecture with a separate quantum data-plane and a conventional control plane shown above (similar to DOE UltraSceinceNet a decade ago).

- **Quantum Data Plane**: The Quantum Data plane consists of links of dark fibers connecting quantum switches and repeaters, which in turn, connect to quantum computers, memory and sensors. Since the current reach is limited to local areas, it will begin as a collection of site networks at laboratories.
- **Conventional Control Plane**: The Control plane provides management access to quantum devices for configuration and provisioning via control nodes with firewall and encryption capabilities.

Continuous Test and Transition Infrastructure: We propose an infrastructure with a control plane connecting multiple sites via encrypted tunnels over conventional networks consisting of the following:

- **Site Quantum Networks**: Individual site networks supported by their fiber plants connect laboratories that house and connect to their quantum devices for testing and interoperability.
- **Site Control Planes**: Sites are connected over individual control planes with control hosts with Software Defined Networking capabilities, which can be peered with other networks via ESnet.
- **Progressive Expansion**: Initially, sites will develop individual data planes with their specific quantum devices and fiber connections, and mechanisms to interface with conventional networks. They progressively expand and interconnect, under a wide-area ecosystem of peered control planes for device testing, interoperability development and roll off into production environments.