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Networking for Practical Quantum Applications

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Like artificial intelligence, large language models, and the metaverse, quantum technology is very much a topic of current interest. Quantum technology promises to leverage quantum mechanics to achieve previously inconceivable goals in computational complexity, speed and security in communications, and precision and accuracy in sensing and measurement. Quantum mechanics help us understand how the smallest particles in our universe behave, often contrary to our classical understanding of the visible world.

Quantum technology has been heralded as revolutionary; however, like the other technologies mentioned, it can be challenging for the average person to separate fact from fiction, and hyperbole from truth. Much of quantum technology remains in the early stages of development as researchers, scientists, and engineers attempt to leverage quantum mechanics to achieve great leaps forward.

So, suppose we have yet to realize practical quantum hardware. Why should we consider efforts to connect incipient processors, sensors, or communications equipment into a quantum version of the classical internet? Here, we will explain what composes a quantum network, why they are important, the key considerations for designing and installing one, and what quantum networks can do for us both today and in the future. We will also introduce you to the first commercial quantum network built by Chattanooga's energy and connectivity provider, EPB, with the help of Qubitekk. Telecommunications professionals will benefit from understanding this emerging technology and the role existing fiber networks play in designing, installing, and operating quantum networks.

What is a Quantum Network?

A quantum network is a type of telecommunications network that uses quantum phenomena to transmit information securely and efficiently. Unlike classical networks that use electrical or light signals to transmit data, quantum networks employ quantum properties of light such as photonic superposition, coherence, and entanglement.

Quantum networks comprise five key elements: a physical layer, quantum sources, quantum detectors, coherence controls, and electronics and software. The physical layer consists of the medium over which quantum bits—or qubits—are transmitted. The primary means is over terrestrial optical fiber. Free-space optical transmission—photon transmission through air or space—is also possible with an appropriate transmitter and receiver, however.

Quantum sources are devices that generate quantum states or particles with specific properties. The exact nature of these states or particles depends on the type of quantum source. For example, a single-photon source generates individual photons, while an entangled photon source produces pairs of photons that are interconnected such that a change in the state of one photon will instantly change the state of the other, no matter how far apart they are. These quantum states are critical for many applications in quantum computing, sensing, and communications.

Quantum detectors are devices designed to measure or detect quantum phenomena, such as individual particles or specific quantum states. A single-photon detector is a type of quantum detector, specifically designed to measure and detect single photons—the elementary particles of light. There are different types of single-photon detectors, including photomultiplier tubes (PMTs), avalanche photodiodes (APDs), and superconducting nanowire single-photon detectors (SNSPDs). Each type has its own advantages and limitations in terms of sensitivity, efficiency, and response time, which makes them suitable for different applications.

Coherence controls improve the stability, integrity, and usability of quantum information transmitted over quantum networks. Quantum states are delicate and can be easily disturbed or destroyed—known as decoherence--which leads to a loss of quantum information. Controlling and extending coherence improves network performance. Lastly, like classical networks, quantum networks require electronics and software to configure and control the network. Timing is critical to distinguishing correlated qubits from random noise. Control plane software enables maintenance and configuration of the network for maximal usability.

Why are Quantum Networks Relevant?

Quantum networks provide two main benefits: 1) connectivity for quantum processors, sensors and communications systems and 2) unparalleled security for information in transit. Given the ubiquitous nature of today's internet, the first benefit will be easily understood. Networking quantum hardware magnifies computational power, information sharing, detection sensitivity, precision, and accuracy. Secondly, quantum networks also offer an unprecedented level of security that is virtually impossible to breach. Moreover, attempts to do so are immediately detectable. Information is encoded in a way that it cannot be intercepted or manipulated without detection, ensuring that the data is transmitted securely. Through a principle referred to as the "no cloning theorem," any attempt to measure or manipulate the quantum state of a particle will destroy the information it contains. Therefore, any attempt to intercept or hack a quantum transmission will be detected, which alerts the sender and receiver to the breach. Near-term use cases for quantum networks, beyond pure research and development, likely include improved security for communications, specialized sensors for critical infrastructure and public safety, and precision timing distribution.

The promise of user-defined R&D, however, makes the case for widespread access so compelling. Small-scale, community-accessible commercial quantum networks available for hardware, software, and application designers and developers will be where American creativity and entrepreneurial spirit will be unleashed. Much like actual users developed the most compelling applications for the Internet, we believe users of quantum networks will come up with cases we can't even imagine yet.

The Nation's First Commercial Quantum Network

In 2022, EPB of Chattanooga and Qubitekk joined together to design, build, and launch America's first industry-led, commercially available quantum network designed for running equipment and applications in an established fiber optic environment—EPB Quantum Network℠ powered by Qubitekk. Built to accelerate the commercialization of quantum technologies, EPB Quantum Network is designed to generate, distribute, and measure qubits across an established fiber optic network connecting businesses, entrepreneurs, researchers, government, and universities to the quantum future.

Even prior to its official opening, EPB Quantum Network already catalyzes collaboration among different players in the burgeoning quantum marketplace. Using equipment provided by Qubitekk and Quantum Opus, software by Aliro, fiber optic cable from OFS, and the fiber optic network owned by EPB, the development of this network is a first in the industry and a promising resource for entrepreneurs in quantum technology who do not have access to private business and government labs.

EPB of Chattanooga launched the nation's first gig-speed community-wide internet in 2010. Since then, the municipal utility has continued to invest in the network, which spans 9,000 miles and is halfway through a $70 million upgrade that allowed EPB to launch America's first community-wide 25 Gig internet service last summer. EPB Quantum Network currently operates on a dedicated underground fiber optic network that mitigates weather disturbances and adds a level of protection against cyberattacks. Although the network is separate from EPB's broader community-wide fiber optic system today, there is enormous potential for scalability as advances continue in the quantum industry. Already, EPB Quantum Network houses 10 nodes—or user spaces—with capacity to add more as user needs evolve.

Locally, in Chattanooga, momentum is growing to support the establishment of a quantum ecology to grow jobs, boost workforce development, and generate business support. In March, the city launched Gig City Goes Quantum to leverage EPB Quantum Network to prepare for education, jobs, and business opportunities in the emerging quantum technology sector. The community-wide initiative garnered support from community leaders, companies, schools, and universities. A key partner, the University of Tennessee at Chattanooga, plans to operate a node on the network as part of their Quantum Information Science and Engineering initiative to establish excellence in education, innovation, and economic development.

The network is available to both public and private sectors, and can be configured for running existing applications, testing new quantum technologies, or validating equipment performance. Built specifically to accelerate the development, adoption, and integration of quantum products, EPB Quantum Network is flexible, private, easy to use, and allows users to maintain complete control over their intellectual property. EPB Quantum Network can serve as a model for smaller-scale quantum networks, spreading momentum across the nation and providing opportunity and access to the scientists and engineers building practical quantum technology applications for tomorrow.

Quantum networks are a promising new technology that has the potential to revolutionize the world of telecommunications. With their unparalleled level of security and speed, quantum networks offer a solution to the ever-growing demand for secure and efficient data transmission. The applications of quantum networks are vast and varied, and as the technology advances, we can expect to see even more innovative applications in the future. Designing and installing a quantum network is a complex process, however, that requires careful consideration of various factors such as hardware selection, environmental conditions, protocol development, and personnel training. As contributors to the nation's first commercial quantum network, we are optimistic about the potential of this technology and look forward to being part of its evolution into our lives in the coming decades.