www.pipelinepub.com
Volume 18, Issue 11

Ready, Set, Switch: The Role of All-Optical Switches in Quantum Networks

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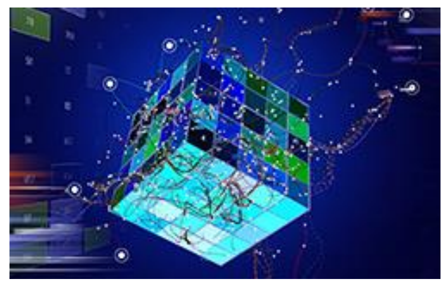

Judging by the sheer number of start-ups in the quantum computing space, as well as the millions of dollars in funding they are receiving, quantum computing is showing all the signs of being the next big thing in tech. [Fortune Business Insights’]() latest forecast estimates that between 2021 and 2028, the market will exhibit a compound annual growth rate (CAGR) of 30.8 percent, growing to be worth $3.1 billion by 2028.

The creation of a quantum Internet would enable the transmission of large volumes of data across immense distances at incredibly high speeds. To capitalize on this, the industry must ensure it understands what is coming and what is needed to take advantage of the future and the opportunities quantum networks will offer.

The quantum networking space and quantum communications in particular hold the promise and potential to make previously impossible communications possible. As efforts accelerate to build this network, one of the key parts for optimized functionality will be an integral switch to manage how data is transmitted between users.

Quantum computing advantages

Before delving into the need for switches, it is worth understanding where we are in the development of the quantum network and its future advantages. Quantum computing utilizes the fundamental principles of quantum mechanics to perform calculations. This will address several problems that are prevalent in classical communication due to computational challenges such as processing power and storage.

The new network capabilities have the potential to enable—and make a reality—a number of important improvements and developments. For example, consider security, an ongoing worry and a hot topic across all types of networks. Quantum computing has the potential to improve security by creating private keys for encryption and secure data transmission using Quantum Key Distribution (QKD). This may mean that eavesdropping attacks, if not impossible, will be minimized, resulting in potentially un-hackable communications. This seems unimaginable at present but could soon become a reality.

Enabling improved healthcare is another exciting development we are likely to see, especially in the design and analysis of molecules for drug development. Quantum computers can simulate the properties of the molecules that classical computers cannot, giving incredible insight into and knowledge for researchers looking to make huge leaps in the discovery of new drugs and the materials to potentially make the incurable curable. Quantum computing may also enable the modeling and simulation of complex natural processes such as weather and climate warming. This has become a critical subject in recent years, and with the recent record-breaking hot weather seen across Europe, this couldn't be timelier and more important.

With a new quantum Internet, we may also see the 'futuristic' dream of teleportation becoming a reality, with information being teleported without physically transmitting it from one location to another. Add accelerated machine learning into the mix and we have an exciting and experimental time ahead. With the delivery of a quantum network, we may soon be able to achieve what we once thought was impossible. But where do we start?

Creating a quantum network

To scale and commercialize quantum computing, quantum networking is needed. To connect a huge number of devices across the globe, the Internet uses hardware components. Similarly, a quantum network requires 'quantum hardware' to enable communication and transmission of information between interconnecting nodes (computers). Quantum networks will provide powerful and secure cloud quantum servers by connecting together and amplifying the capabilities of individual quantum

processors. But how do we create this? Unlike classical computers and contrary to popular perception, quantum computing isn't just a faster Internet; it is something entirely different. Quantum computing uses quantum properties like superposition, entanglement, interference, and uncertainty to achieve a deterministic outcome—the basis for quantum physics.

Qubits are the basic unit of quantum information, carried or housed in a physical device like a chip or processor. You increase the computational potential by increasing the number of qubits that can be processed into controllable quantum states. It is difficult to add more qubits as they are very sensitive to environmental factors like noise, meaning they have very low fault tolerance. When you add qubits, the noise is multiplied.

So, unlike classical computers, which only have their computational power determined by their CPU, a quantum computer's computational power will be able to grow depending on the number of qubits it processes. A key requirement for most quantum communication protocols will be successful distribution. Therefore, to enable many-to-many—networked—quantum communications, a new type of switch capable of routing entangled single photons is needed.

The role of all-optical switches

The role of and need for all-optical switching is growing—and growing rapidly. But until a quantum Internet is built, one of the many ways to realize qubits for larger, stable systems and to transmit over longer distances is to send photon-based qubits over conventional networks, distributing entanglement and routing quantum information to multiple nodes.

There are, however, some challenges. With increases in distance traveled, the photon loss grows exponentially, making it one of the biggest hindrances to quantum transmission. We also see that entanglement degrades or is destroyed with phase decoherence, while moving beyond point-to-point communication can lead to issues with distributed synchronization, making quantum communication challenging.

All-optical switches (OOO) function by selectively switching the entire optical signal on one optical fiber to another optical fiber. Traditional optical-electrical-optical (OEO) switches have a challenge preserving quantum coherence and optical amplifiers will amplify noise as well as the signal, making them less than ideal for quantum transmission. All-optical switches that do not have to regenerate the signal the way OEO switches do have a higher probability of going longer distances and preserving quantum coherence. Therefore, all-optical switches have a unique value proposition over traditional OEO switches as they transmit the original input light signal through a transparent all-optical switch core, without converting it into an electrical format. The transparent nature of all-optical switches makes them protocol-, format- and data-rate agnostic.

Some of the leading quantum research groups worldwide are performing cutting-edge research using all-optical switches. These cutting-edge switches help to address one of the key barriers to a quantum internet by ensuring information that could be lost or distorted travels safely at high speeds, switching all light regardless of wavelength. However, although this technology promises to transform how we connect with the world, we still don’t know the full capabilities of the quantum network, nor when it will be widely operational.

For a truly successful network to become a reality, the industry needs to bring together all the necessary pieces of technology. This can only be done if robust quantum communication ‘ecosystems’ are developed through partnerships and alliances between telecom providers, start-ups, established businesses and research institutions. It will be critical that everyone works together to set standards, develop solutions, and cultivate workers with the right skills for the operation of the network.

There is one thing we know for sure, however: networks 10 years from now are going to be unrecognizable, and that prospect is extremely exciting.