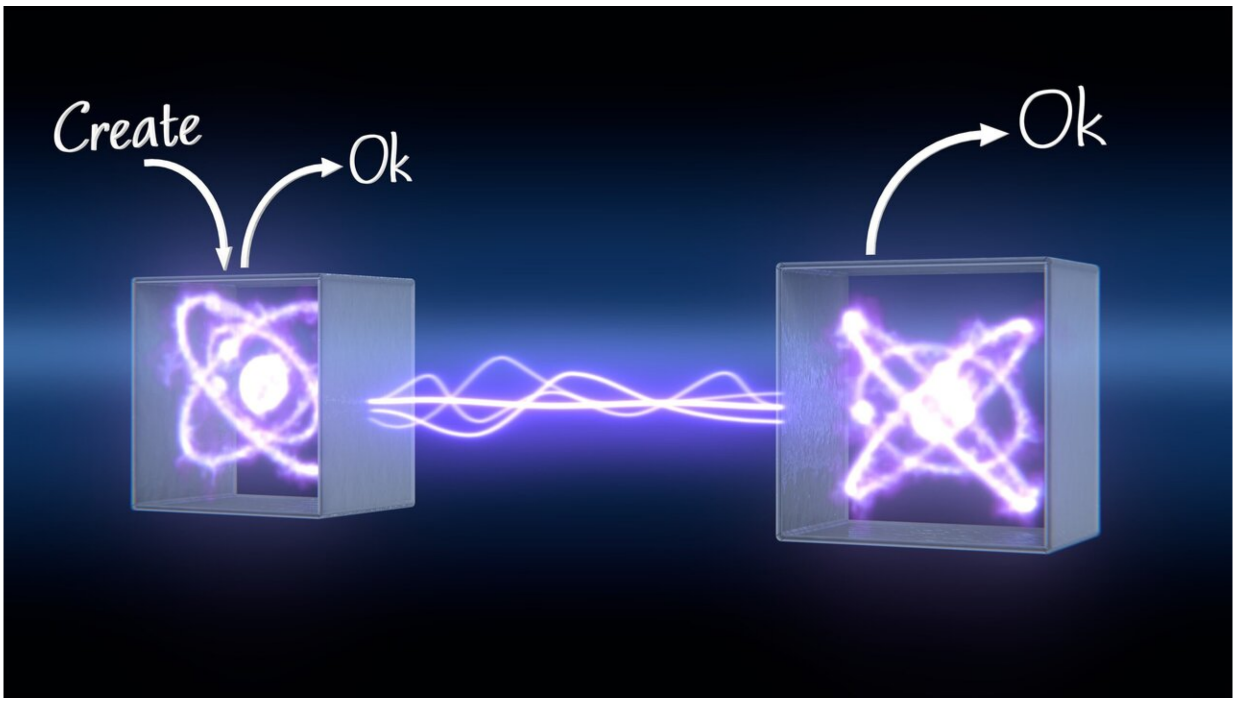
World's first link layer protocol brings quantum internet closer to a reality

August 20 2019



Using the link layer protocol, higher-layer software can request the creation of entanglement without needing to know which quantum hardware system is in the box. Credit: QuTech/Scixel

Researchers from QuTech have achieved a world's first in quantum internet technology. A team led by Professor Stephanie Wehner has developed a so-called link layer protocol that brings the phenomenon of quantum entanglement from experimental physics to a real-world quantum network. This brings closer the day when quantum internet can become a reality, delivering applications that are impossible to achieve via classical internet. The work was presented today at ACM SIGCOMM.

In classical computing, a collection of software layers referred to as the network stack allows computers to communicate with each other. Underlying the network stack are communications protocols, such as the internet protocol or HTTP. Stephanie Wehner explained that one essential protocol used by a network is the link layer protocol, which overcomes the problems caused by imperfect hardware: "All of us use classical link layer protocols in everyday life. One example is Wi-Fi, which allows an unreliable radio signal—suffering from interruptions and interference—to be used to transmit data reliably between compatible devices."

A quantum network, based on transmission of quantum bits, or qubits, requires the same level of reliability. Stephanie Wehner says, "In our work, we have proposed a quantum network stack, and have constructed the world's first link-layer protocol for a quantum network."

It turns out that existing classical protocols cannot help in the quantum world. One challenge is presented by differences between the technologies used. Stephanie Wehner: "Currently, qubits cannot be kept in memory for very long. This means control decisions on what to do with them need to be taken very quickly. By creating this link layer protocol, we have overcome obstacles presented by some very demanding physics."

There are also some fundamental differences between a future quantum internet and the internet that we see today. Stephanie Wehner said that two quantum bits can be entangled: "Such entanglement is like a connection. This is very different to the situation for classical link layer protocols where we typically just send signals. In that case, there is no sense of connection built in at a fundamental level."

Quantum internet

The phenomenon of entanglement forms the basis of a quantum internet. When two fundamental particles are entangled, they are connected with each other in such a way that nothing else can have any share of this connection. Researcher Axel Dahlberg said that this enables a whole new range of applications "Security is one important application. It is physically impossible to eavesdrop on an entangled network connection between two users. To give another example, the technology also allows improved clock synchronization, or it can join up astronomical telescopes that are a long way apart, so they act as a huge single telescope."

Researcher Matthew Skrzypczyk said that an important feature of the proposed quantum network stack and the link layer protocol is that it any future software written using the protocol will be compatible with many quantum hardware platforms. "Someone who makes use of our link layer protocol no longer needs to know what the underlying quantum hardware is. In our paper, we study the protocol's performance on Nitrogen-Vacancy centers in diamond, which are essentially small quantum computers. However, our protocol can also be implemented on Ion Traps, for example. This also means our link layer protocol can be used in the future on many different types of quantum hardware."

Building a quantum network system

Stephanie Wehner said that the next step will be to test and demonstrate a new network layer protocol using the link layer protocol: "Our link layer protocol allows us to reliably generate entanglement between two network nodes connected by a direct physical link, such as a telecom fiber. The next step is to produce entanglement between network nodes which are not connected directly by a fiber, using the help of an intermediary node. In order to realize large scale quantum networks, it is important to go beyond a physics experiment, and move towards building a quantum network system. This is one of the objectives EU-funded Quantum Internet Alliance (QIA)."

More information: A Link Layer Protocol for Quantum Networks, by Axel Dahlberg et al., Preprint: arxiv.org/abs/1903.09778

Provided by Delft University of Technology