Entanglement recycling makes teleportation more practical

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(Phys.org)—Working in the exotic-sounding field of quantum teleportation, physicists are trying to make it easier to transmit quantum information in the form of qubits from one location to another without having the qubits actually travel through the intervening space. One challenge in quantum teleportation protocols lies in producing the enormous amount of entanglement required to send each qubit, a requirement that makes teleportation impractical for real applications. To overcome this problem, the scientists have proposed the idea of entanglement recycling, where the entanglement needed to send a qubit can be reused to send other qubits, greatly reducing the amount of entanglement required.

The physicists, Sergii Strelchuk at the University of Cambridge in the UK, Michał Horodecki at the University of Gdansk in Poland, and Jonathan Oppenheim of the University of Cambridge and the University College of London, have published their study on entanglement recycling in a recent issue of Physical Review Letters.

The physicists looked at a recently introduced teleportation protocol called port-based teleportation. Like all quantum teleportation protocols, port-based teleportation requires that the sender, Alice, and the receiver, Bob, share an entangled state, called a resource state, before sending qubits. To teleport a qubit, Alice first performs a measurement on the qubit's state and her part of the entangled resource state, destroying both qubits in the process. She then communicates her measurement outcome as classical information to Bob. By carrying out a certain operation, Bob

can transform his resource state into the teleported state from Alice.

In port-based teleportation, Bob's operation involves using Alice's measurement outcome to discard all of his ports except for the one indicated by the measurement outcome. That port contains the teleported state. However, this process destroys the entanglement between Alice and Bob, so they have to generate a new entangled resource state every time they teleport a qubit. Such a large amount of entanglement isn't suitable for practical purposes.

Before the physicists could show how entanglement recycling might help, they first had to develop a generalized teleportation protocol that bridges the two main types of protocols. As they explained, all currently known teleportation protocols can be classified into two groups (the symmetric permutation group and the Pauli group). The two groups differ in how they incorporate entanglement: the first group of protocols requires an infinitely large amount of shared entanglement to teleport a state, while the second group uses less entanglement but requires that Bob apply a correction after receiving Alice's measurement, which isn't necessary in the first group.

The physicists developed a generalized protocol by modifying the port-based teleportation protocol so that it shared some properties of both groups. The scientists could then show how to recycle the entanglement produced in the generalized protocol by keeping the resource state and reusing it for subsequent teleportations. They showed that the original resource state doesn't degrade very much and retains a sufficiently high fidelity to be reused.

The scientists incorporated the concept of entanglement recycling into two new protocols based on the generalized port-based teleportation protocol. In one protocol, qubit states were teleported sequentially, one at a time, using the same resource state. In the second protocol, multiple

qubit states were teleported simultaneously, using the recycled resource state in a different way. In the simultaneous case, Alice teleports each qubit to a unique port, and makes a measurement on all of these states and the resource state in one round, which she then sends to Bob. In both protocols, the resource state degrades proportionally to the number of qubits teleported, whether sequentially or simultaneously, placing a limit on the total number of qubits that can be teleported by one resource state.

The scientists hope that, by reducing the amount of entanglement required for quantum teleportation protocols, entanglement recycling could open the doors to implementing teleportation in quantum computing applications.

More information: Sergii Strelchuk, Michał Horodecki, and Jonathan Oppenheim. "Generalized Teleportation and Entanglement Recycling." PRL 110, 010505 (2013). DOI: 10.1103/PhysRevLett.110.010505 (Arxiv: arxiv.org/abs/1209.2683)