# Quantum Teleportation

In matters relating to quantum information theory, it is convenient to work with the simplest possible unit of information: the two-state system of the qubit. The qubit functions as the quantum analog of the classic computational part, the bit, as it can have a measurement value of *both* a 0 *and* a 1, whereas the classical bit can only be measured as a 0 *or* a 1. The quantum two-state system seeks to transfer quantum information from one location to another location without losing the information and preserving the quality of this information. This process involves moving the information *between carriers* and not movement of the *actual carriers*, similar to the traditional process of communications, as two parties remain stationary while the information (digital media, voice, text, etc.) is being transferred, contrary to the implications of the word "teleport." The main components needed for teleportation include a sender, the information (a qubit), a traditional channel, a quantum channel, and a receiver. An interesting fact is that the sender does not need to know the exact contents of the information that is being sent. The measurement postulate of quantum mechanics—when a measurement is made upon a quantum state, any subsequent measurements will "collapse" or that the observed state will be lost—creates an imposition within teleportation: if a sender makes a measurement on their information, the state could collapse when the receiver obtains the information since the state has changed from when the sender made the initial measurement.

For actual teleportation, it is required that an entangled quantum state or Bell state be created for the qubit to be transferred. Entanglement imposes statistical correlations between otherwise distinct physical systems by creating or placing two or more separate particles into a single, shared quantum state. This intermediate state contains two particles whose quantum states are dependent on each other as they form a connection: if one particle is moved, the other particle will move along with it. Any changes that one particle of the entanglement undergoes, the other particle will also undergo that change, causing the entangled particles to act as one quantum state. These correlations hold even when measurements are chosen and performed independently, out of causal contact from one another, as verified in Bell test experiments. Thus, an observation resulting from a measurement choice made at one point in spacetime seems to instantaneously affect outcomes in another region, even though light hasn't yet had time to travel the distance; a conclusion seemingly at odds with special relativity. This is known as the EPR paradox. However such correlations can never be used to transmit any information faster than the speed of light, a statement encapsulated in the no-communication theorem. Thus, teleportation as a whole can never be superluminal, as a qubit cannot be reconstructed until the accompanying classical information arrives.

The sender will then prepare the particle (or information) in the qubit and combine with one of the entangled particles of the intermediate state, causing a change of the entangled quantum state. The changed state of the entangled particle is then sent to an analyzer that will measure this change of the entangled state. The "change" measurement will allow the receiver to recreate the original information that the sender had resulting in the information being teleported or carried between two people that have different locations. Since the initial quantum information is "destroyed" as it becomes part of the entanglement state, the no-cloning theorem is maintained as the information is recreated from the entangled state and not copied during teleportation.

The quantum channel is the communication mechanism that is used for all quantum information transmission and is the channel used for teleportation (relationship of quantum channel to traditional communication channel is akin to the qubit being the quantum analog of the classical bit). However, in addition to the quantum channel, a traditional channel must also be used to accompany a qubit to "preserve" the quantum information. When the change measurement between the original qubit and the entangled particle is made, the measurement result must be carried by a traditional channel so that the quantum information can be reconstructed and the receiver can get the original information. Because of this need for the traditional channel, the speed of teleportation can be no faster than the speed of light (hence the no-communication theorem is not violated). The main advantage with this is that Bell states can be shared using photons from lasers making teleportation achievable through open space having no need to send information through physical cables or optical fibers.

Quantum states can be encoded in various degrees of freedom of atoms. For example, qubits can be encoded in the degrees of freedom of electrons surrounding the atomic nucleus or in the degrees of freedom of the nucleus itself. Thus, performing this kind of teleportation requires a stock of atoms at the receiving site, available for having qubits imprinted on them.

As of 2015, the quantum states of single photons, photon modes, single atoms, atomic ensembles, defect centers in solids, single electrons, and superconducting circuits have been employed as information bearers.

Understanding quantum teleportation requires a good grounding in finite-dimensional linear algebra, Hilbert spaces and projection matrixes. A qubit is described using a two-dimensional complex number-valued vector space (a Hilbert space), which are the primary basis for the formal manipulations given below. A working knowledge of quantum mechanics is not absolutely required to understand the mathematics of quantum teleportation, although without such acquaintance, the deeper meaning of the equations may remain quite mysterious.