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Quantum Entanglement an Indispensable Tool of Quantum Teleportation

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ABSTRACT

One of the most crucial procedures in quantum information is quantum teleportation. Quantum teleportation, which makes use of the physical resource of entanglement, is a fundamental primitive in many quantum information tasks and is a crucial component of quantum technologies. It is essential to the ongoing development of quantum networks, quantum computing, and quantum communication. Here, the practical applications of Bell states, algebra of entanglement, and quantum dense coding are highlighted. The fundamentals of quantum entanglement are described, along with its characteristics and the Einstein-Poldolsky-Rosen dilemma. By separating its distinctive properties, this paper demonstrated that teleportation will be used practically for quantum key distribution in the very near future. It also revealed the fundamental theoretical concepts behind quantum teleportation.

Keywords:
Quantum Teleportation,
Quantum Information,
Quantum computing,
Quantum Entanglement.

INTRODUCTION

More than 20 years have passed since the discovery of quantum teleportation, which is undoubtedly one of the most intriguing and thrilling applications of quantum physics' oddities. This intriguing concept was confined to science fiction prior to this historic discovery. Charles H. Fort first introduced the term "teleportation" in a book published in 1931. Since then, it has been used to describe the process of moving goods and humans from one place to another without actually traveling there. Since then, it has ingrained itself into popular culture, possibly best represented by the well-known catchphrase "Beam up, Scotty" from Star Trek. (Pirandola et al., 2015).

Many of the aforementioned characteristics are shared by a quantum information protocol known as quantum teleportation, which was discussed in a 1993 conference by Benett et al. The physical components of the original system stay at the sending location while an unknown quantum state of a physical system is measured and then rebuilt or reassembled at a distant location. Superluminal communication is not allowed in this process, which calls for classical communication. Most significantly, it needs quantum entanglement as a resource. In fact, the quantum information technique that best illustrates the nature of quantum entanglement as a resource is quantum teleportation: According to the principles of mechanics, such a quantum state transfer would not be feasible without it (Horodecki et al., 2009; Pirandola et al., 2015).

Two significant applications of quantum information theory that benefit from the strength of quantum entanglement are superdense coding and teleportation. With the former allowing the transfer of classical bits using quantum bits and the later allowing the transfer of quantum bits using classical bits, these two protocols can be thought of as duals of one another. Both protocols assume that there is a noiseless channel between nodes that share a Bell pair. It might not be able to produce flawless Bell pairings in practice. The channels utilized for traditional communication in the lab are typically loud(Ankur and Shayan, 2016).

In 1993, Pati and Agrawal examined the usage of pure bipartite states that were not maximally entangled and assessed the fidelity of teleportation, referring to it as probabilistic teleportation. Popescu (1994) used mixed bipartite states to demonstrate that teleportation is feasible. Horodecki et al. (1999) demonstrated that not all entangled mixed states are suitable for teleportation. Horodecki et al. rejected a number known as the totally entangled fraction in order to determine if an entangled state might be utilized for teleportation. It was demonstrated that entangled states can be utilized for teleportation as long as this proportion is higher than a specific threshold.

Distributed computing, cryptography, quantum communication, parallel computing, and other technologies all take advantage of teleportation and entanglement. Among them, cryptography is the thriving subject where, in the very near future, teleportation and entanglement could be used effectively. Public key encryption and shared key encryption are two options in classical cryptography. However, because a quantum computer can factor the prime product very quickly, the public key is susceptible to attack. Distributing random numbers becomes problematic since, despite the shared key's security, it necessitates a large number of shared random numbers that cannot be used more than once. Therefore, the solution is quantum teleportation/entanglement.

Tittel et al., (2000) and Jennewein et al., (2000) have shown that entangled photons can be used to generate and distribute a perfectly secure quantum key (for communication and decoding of encrypted messages). Users can delete the compromised portions of the data since any attempt by eavesdroppers to intercept the quantum key will change the contents in a way that can be detected. The use of teleportation for quantum key distribution is being researched.

Quantum Bits

Information is manipulated by all computers, and the quantum bit, or qubit, is the unit of quantum information. While qubits can be in a linear superposition of the two classical states, classical bits can only have a value of 0. A quantum bit can be in any state a|0>+b|1> if the classical bits are denoted by |0> and |1>. In this case, a and b are complex numbers known as amplitudes, and |a|2 +|b|2 = 1. An irreversible disruption is caused by any effort to measure qubits. For instance, the qubit makes a probabilistic judgment when the most direct measurement on a|0>+b|1>; In either scenario, the measuring device indicates which option has been selected, but all prior knowledge of the initial amplitudes a and b is erased. With probability |a|2, it becomes |0 >, and with complementary probability |b|2, it becomes |1>.

A physical system of n qubits needs 2n complex numbers to express its state, in contrast to classical bits, which may be described by a single string of n zeros and ones. Two qubits, for instance, could be in the states a|00>+b|01>+c|10>+d|11>. for any complex number between a, b, c, and d, with the sole restriction being |a|2 +|b|2 +|c|2 +|d|2 = 1.

An additional qubit feature is an entanglement property. Take the two-qubit state (|00>-|01>-|10>+|11>)/2 into consideration. This state can be factored into the product of two one-qubit states, each of which is (|0>-|1>)/(√2), making it simpler than it first appears.In a similar vein, many n-qubit states can be described using only 2n numbers, which is significantly fewer than the 2n numbers typically used, because they can be expressed in factored form.

Certain unusual states, such (|01>-|10>)/(√2), cannot be factored, though. With equal probability (1/(√2))2, these two qubits can be measured to produce either 0 and 1 or 1 and 0, but it is not known which of these two results will be obtained until the measurement is actually carried out. There is no classical comparable for this. (Brassard et al., 1998).

Single Qubits

A two-level system with the levels |0> and |1> as its quantum states can be expressed as follows:

$$|\psi>=a|0>+b|1> \quad (1)$$

The complex numbers a and b in this case meet the normality criterion |a|2+|b|2=1. The idea of quantum bits, or qubits, originated from the ability of such a system to store binary information in analogy with a classical bit having logical states 0 and 1. Unitary transformations that maintain the norm are operations that map one quantum state | ψ >=a|0>+b|1> onto another quantum state |ψ'>=a'|0>+b'|1>. As unitary 2x2 matrices acting on a quantum state vector | ψ >, they can be written as follows:

$$|\psi>=\begin{pmatrix} a \\ b \end{pmatrix} \quad (2)$$

An example of such operation is the Hadamard operation:

$$H=\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \quad (3)$$

which creates an equal superposition (|0>|1>) between the states |0> and |1>./2. Representing a two-level system as a point on a unit sphere with polar coordinates, as illustrated in Fig. 1:1, is a practical method of visualizing its state. The vector λ=(cosθ sinθ, sinθ sinθ, cosθ) is the Bloch vector, and this image is commonly referred to as the Bloch sphere representation in this image can be written as:

$$|\psi>=\exp i\Upsilon[\cos(\frac{\theta}{2})|0>+\exp i\varphi\sin(\frac{\theta}{2})|0>] \quad (4)$$

In this case, the global phase factor expiϒ is typically left out because it has no discernible impact. In the Bloch sphere representation, unitary operations take the form of Bloch vector rotations.

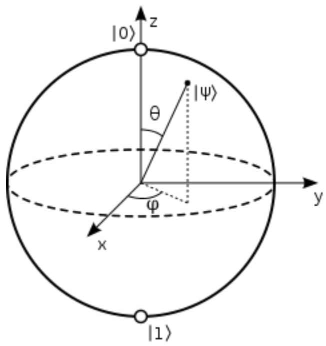

Figure1: Bloch sphere representation of a two level system

Thereby, rotations about the x-,y-and z-axes are given respectively by:

$$R_x(\theta) = \exp(-i\tfrac{\theta}{2}X) = \cos\tfrac{\theta}{2}I - i\sin\tfrac{\theta}{2}X = \begin{pmatrix} \cos\frac{\theta}{2} & -i\sin\frac{\theta}{2} \\ -i\sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix} \quad (5)$$

$$R_y(\theta) = \exp(-i\tfrac{\theta}{2}Y) = \cos\tfrac{\theta}{2}I - i\sin\tfrac{\theta}{2}Y = \begin{pmatrix} \cos\frac{\theta}{2} & -\sin\frac{\theta}{2} \\ \sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix} \quad (6)$$

$$R_z(\theta) = \exp(-i\tfrac{\theta}{2}Z) = \cos\tfrac{\theta}{2}I - i\sin\tfrac{\theta}{2}Z = \begin{pmatrix} \exp(-i\frac{\theta}{2}) & 0 \\ 0 & \exp(i\frac{\theta}{2}) \end{pmatrix} \quad (7)$$

Where X, Y and Z are the pauli matrices and I the identity matrix. These matrix are defined by:

$$X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad (8)$$

$$Y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad (9)$$

$$Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad (10)$$

$$I = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad (11)$$

Multiple Qubits

The 2N product states of the individual qubit states |0>,|1> provide an appropriate set of basis states for a system of N qubits:

$|n\rangle = |i_N\rangle \otimes i_N - 1 > \otimes \ldots.. \otimes |i_1\rangle$ (12)

where n = ∑_(k=1)^Ni_(k.) 2k-1 and ik ∈ 0;1. Please take note that the first qubit in this tensor product has the rightmost state, which may initially seem counterintuitive. These computational base states can be decomposed into any N qubit quantum state. For instance, when there are two qubits, we have:

$|\psi\rangle = a_0|00\rangle + a_1|01\rangle + a_2|10\rangle + a_3|11\rangle$; (13)

where the normality requirement ∑_(i=0)^(N-1)|ak|2 = 1 is obeyed by the coefficients ak. Unitary NXN matrices explain quantum operations working on a system of N qubits. The operation I ⊗X, for instance, which involves applying the identity operation to the second qubit and X to the first, is explained by:

$$I \otimes X = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \quad (14)$$

Where the matrix is notated with respect to the basis order (|00>, |01 >, |10 >, |11>).

Controlled Quantum Gates

Controlled operations are those in which the state of one qubit is altered in response to the state of another qubit. The controlled -NOT or CNOT operation is a crucial illustration of a controlled operation:

$$U^{21}_{CNOT} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \quad (15)$$

If the second qubit (the control qubit) is in state |1>, this operation flips the first qubit's (the target qubit's) state; if it is in state |0>, it leaves the target qubit unaltered. To indicate which qubit serves as the control and which as the target qubit, we use the notation UCNOTcontrol;target. The controlled Z or phase gate, which is another controlled two-qubit operation, is expressed as follows:

$$\emptyset = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -0 \end{pmatrix} \quad (16)$$

The roles of the control and target qubits are interchangeable in the context of the phase gate. Since the controlled NOT gate can be broken down into two Hadamard operations and a phase gate, phase gates and controlled NOT operations are closely related:

$U^2_{CNOT} = H_1 . \emptyset . H_1$ (17)

where $H_1 = I \otimes H$ is the Hadamard operation acting on the first qubit:

$$H_1 = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & -0 \end{pmatrix} \quad (18)$$

The target qubit is the qubit to which the Hadamard operations are applied. For quantum computing, controlled operations are essential. It has been demonstrated that single qubit rotations and controlled NOT operations are universal (Mark, 2005; Barenco et al., 1995), meaning that a combination of single qubit and controlled NOT operations can actualize any arbitrary unitary operation.

Measurement in the Bell Bases

A projective measurement in the Bell state basis is a specific case of a measurement. The four Bell states, which are represented in the computational basis as follows, provide this basis:

$\psi_+ = \frac{1}{\sqrt{2}}(|10>+ |01>);\ = \psi_- \frac{1}{\sqrt{2}}(|10>|01>);\emptyset_+ = \frac{1}{\sqrt{2}}(|00>+|11>),\emptyset_- = \frac{1}{\sqrt{2}}(|00>|11>).$ (19)

It is preferable to do measurements in the computational basis (|0>;|1>) in the majority of experimental setups. Therefore, the Basis states (∅+, ∅-, ψ+, ψ-) must be mapped into the computational basis states of two qubits (|00>;|01>;|10>;|11>) in order to make a measurement in the Bell basis. This is accomplished by applying a Hadamard operation H1 to qubit 1 after first applying a controlled NOT UCNOT12, in which qubit 1 is the control qubit and qubit 2 is the target qubit. Take, for instance, how these operations affect the Bell state +:

$\frac{1}{\sqrt{2}}(|10>+|01>) \xrightarrow{U12} CNOT\ \frac{1}{\sqrt{2}}(|10>+|11>)=\frac{1}{\sqrt{2}}|1>(|0>+|1>) \rightarrow^{H1} |10>.$ (20)

It's interesting to note that this process is bidirectional; that is, Bell states are produced by applying a Hadamard operation first, followed by the CNOT gate, starting with the computational basis states.

Sequences of Quantum Operations: Quantum Circuits

The most basic operations that can be used on a single qubit or a register of several qubits were presented in the preceding sections. Generally speaking, a quantum computer algorithm will have a large number of these operations. An analogy to classical computing, where a computation is constructed from a network of several logic gates, such a series of operations is also known as a quantum circuit. The following introduces the related rules and notations and illustrates various approaches of writing quantum algorithms. Initially, in the case of quantum states employing the bra-and-ket-notation.

The order of the qubits will be |qubitn,…, qubit2,qubit1>. The same order will apply to the outer products of operators, so that, for instance, I ⊗ I ⊗ X indicates an X-operation on qubit 1 and the identity operation on qubits 2 and 3. The product of the related operators can be used to express further unitary operations on a register of qubits, resulting in the total unitary operation U= …OP3OP2OP1| ψm >.

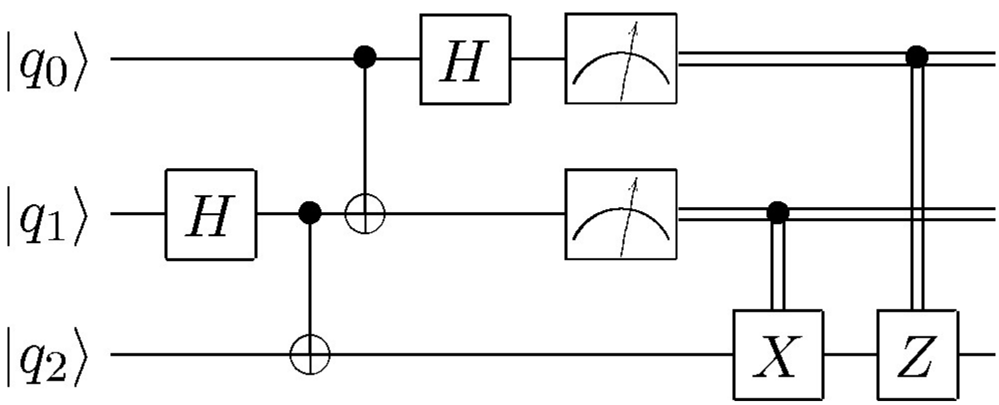

Figure 2: An illustration of a quantum circuit

Quantum teleportation is being implemented via the circuit. From left to right is the temporal order. One qubit's state is represented by each horizontal line. Various symbols are used to indicate the operations performed on the qubits.

Fig. 2 illustrates a quantum circuit in still another manner. The following is how one should interpret this graphical depiction of a register of qubits and the actions on them: One qubit's state is represented by each horizontal line. Different symbols are used to represent the operations that are performed on the qubits. When reading the circuit from left to right, time increases.

Entangle States of Two Qubits

The topic of whether a quantum system's quantum state can be broken down into a product of its subsystem states is typically linked to a notion of entanglement of a quantum system with numerous subsystems. A bipartite system with two qubits in a pure state can be used to demonstrate this method. If a state of this bipartite system can be expressed as a product of the states of its subsystems, it is referred to as a product state or separable:

$\Psi = \psi_1 \otimes \psi_2$ (21)

Both subsystems are totally independent of one another in this scenario. The status of one subsystem will not be impacted by a measurement made on the other. There will be no correlation between the measurement findings for both subsystems.

On the other hand, an entangled state is one that cannot be expressed as a product of subsystem states. The Bell states are a well-known illustration of entangled states. The subsystems are no longer autonomous in this situation. With highly correlated measurement findings, a measurement on one subsystem will cause a state reduction in both subsystems. The following is an expansion of this definition for mixed states. If there is a decomposition into product states, a state that is characterized by the density matrix ρ is considered separable:

$\rho = \sum_i p_{i.p_1} \otimes p_{2,} p_i > 0, \sum p_i = 1$ (22)

When such a decomposition is absent, an entangled mixed state is identified. Classical correlations, which are defined by the probabilities, can also exist in mixed states in addition to quantum correlations.

Unfortunately, it is difficult to confirm explicitly whether or not a decomposition such as that shown in Eq. 22 exists for a given density matrix. However, a criterion that depends on the behavior of the partial transposition ρPT exists for bipartite systems to identify whether a state is separable or not. The definition of the partial transpose ρPT is:

$\rho^{PT} = (\sigma_x \otimes I).\ \rho$ (23)

It has been demonstrated that a mixed state is entangled if and only if the eigenvalue of its partial transposition is negative (Mark, 2005: Asher, 1996).

Pioneering Effects Based on Entanglement

Quantum Key Distribution Based on Entanglement

A. Ekert was the first to develop quantum information theory, which uses entanglement (Ekert, 1991; Horodecki et al., 2007). Two truths were widely known: presence of a highly linked state

$|\psi^-> = \frac{1}{\sqrt{2}} (|0>|1> - |1>|0>)$ (24)

and Bell inequalities, which these states contradict. Ekert demonstrated how they can be combined to provide a private cryptographic key. In contrast to the original BB84 technique, which makes use of direct quantum communication, he thus established an entanglement-based quantum key distribution. The following is the core of the protocol: Bob and Alice can get the EPR pairings from a source. Alice and Bob obtain a string of perfectly (anti)correlated bits, or the key, by measuring them in basis (|0 >, |1>). They examine Bell inequalities on a subset of pairings to confirm their security. In general, the values would have existed prior to the measurement if Eve had knowledge of the values that Alice and Bob obtain in the measurement.

There would be no violation of Bell's inequality. It appears that no one can know the values if Bell inequalities are broken because they do not exist prior to Alice and Bob's measurement. Polarization entangled photons from spontaneous parametric down conversion (Naik et al., 2000) and entangled photons in energy-time (Tittel et al., 2000) were used in the first implementations of the Ekerts encryption protocol. There were two possible directions for quantum cryptography research after Ekert's concept. One approach, as proposed by Bennett et al. (1992), was to view the violation of Bell inequality as merely confirming that Alice and Bob have good EPR states, as this is adequate for privacy:

No one can know the outcomes of Alice and Bob's measurements if they are in a true EPR condition. This is what really occurred; only this method was created for a long period. Eve, the eavesdropper in this instance, complies with quantum mechanical laws. Treating the EPR state as the cause of odd correlations that defy Bell inequality was the second approach. This results in a new definition of security: protection from eavesdroppers who adhere only to the no faster than light communication principle rather than the laws of quantum mechanics.

Quantum Dense Coding

There is a realistic limit on the potential miracles that could result from quantum formalism in quantum communication. According to Holevo (1973) and Horodecki et al. (2007), this is the Holevo bound. It basically says that one qubit can only carry one bit of classical information at most. Bennett and Wiesner found a fundamental primitive that can circumvent the Holevo bound in 1992. This primitive is known as dense coding. By transmitting one a priori entangled qubit, dense coding enables the communication of two classical bits.

Let's say Alice can only send one qubit and wishes to send Bob one of four messages. He must send a qubit in one of 22 = 4 states in order to convey two bits with one qubit. Additionally, the states must be orthogonal to one another in order for Bob to distinguish between them and achieve the optimal bound 2. However, a single qubit can exist in only two orthogonal states. Is entanglement useful in this case? Instead, let Bob and Alice be in the same EPR state.

The ingenious notion now is that the pair of entangled qubits together, rather than the sent qubit, should be in four orthogonal states. Let's see how it functions. Let's say Bob and Alice are in the same singlet state. Alice rotates her qubit, which is entangled with Bob, with a matching transformation if she wishes to inform Bob of one of the four occurrences (0,1,2,3).

$$\sigma_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix},\ \sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},\ \sigma_2 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix},\ -i\sigma_3 = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \quad (25)$$

The matching | ψk> Bell state is created by rotating Alice's qubit's singlet state by σk. Bell states are mutually orthogonal, therefore for k ≠ k | ψk >= [σk]A ⊗IB | ψ0 > is orthogonal to |ψk1 > = [σk1]A IB| ψ0 >. Bob can now distinguish between the four Bell states and deduce k if he receives Alice's portion of the entangled state after rotation. Bob has received log4=2 bits of information as a result of Alice sending one qubit.

Why does the Holevo bound not conflict with this? This is because Bob's qubit and the communicated qubit were already entangled. Holevo bound does not apply in this scenario, hence this peculiar occurrence can occur. Additionally, take note that two qubits were transferred in total; one was required to share the EPR state. Another way to look at this is that sending the first half of the singlet state—let's say at night, when the channel is less expensive—equals sending one bit of possible communication.

Therefore, it is equivalent to opening the door to future communication: Alice might not know what she would say to Bob in the future at this point. She is aware of what to say during the day, but she is only able to send one qubit due to the costly channel. In other words, she only sent one real message. Nevertheless, she uses both the actual and potential bits to transmit in a total of two classical bits when sending the second half of the singlet, much like in dense coding protocols. A good quantum memory for storing EPR states is assumed to exist in Alice and Bob, which is still beyond the capabilities of present technology.

Alice and Bob are in the same pure maximally entangled state in the original dense coding process (Barenco and Ekert, 1995; Bose et al., 2005; Bru et al., 2005; Hausladen et al., 1996; Mozes et al., 2005; Ziman and Buzek, 2003; Horodecki et al., 2007).

Entanglement Swapping

Typically, a direct contact between two particles that are placed close to one another is the source of quantum entanglement. Can two particles that have never previously interacted become entangled (correlated in a quantum way)? (Bennett et al., 1996 a; Yurke and Stoler, 1992b; Zukowski et al., 1993) The response is in the affirmative. Let Bob and David share a maximally entangled state, and Alice and Clare share a maximally entangled state $|\emptyset+> = 1/\sqrt{2}\,(|00>+|11>)$:

$$|\emptyset^+>_{AC} \otimes |\emptyset^+>_{BD} \quad (26)$$

It is clear that such a situation may be created so that particles A and D have never seen one another. Clare and Bob now measure together in Bell basis. It turns out that the particles A and D collapse to some Bell state for all possible outcome. Alice and Bob can execute local rotation to achieve the entangled state AD+ if they learn the outcome. Because they came from distinct sources, the particles of Alice and David are entangled in this fashion even if they never had direct contact.

It is evident that this is the same as teleporting one EPR pair through the other. Any pair can be selected to be the channel or the teleported pair because the protocol is symmetric. This concept has been used to implement quantum repeaters (Dur et al., 1999), which enable the theoretical distribution of entanglement among parties that are arbitrarily separated. Bose et al. (1998) adapted it to a multipartite context.

One application of swapping is in multipartite state distribution, which is helpful in quantum cryptography, for instance. The requirements for the optical implementation of teleportation and entanglement switching have been determined in (Zukowski et al., 1993).Accordingly, entanglement switching was achieved in the laboratory (Horodecki et al., 2007; Pan et al., 1998).

Quantum Teleportation Process

The practical use of the quantum teleportation principle is demonstrated by the experimental work of Benett (1993) and subsequent theoretical and experimental work by others. The question of whether quantum entanglement might be used to design a teleportation procedure to move information between remotely distant quantum systems non causally (i.e., at FTL speed) was finally resolved by this astounding technical feat. We are now providing an inferred overview of the actual teleportation process, which is based on the outline of (Benett, 1993). This is a multi-step process of teleporting any particle or photon's quantum state | χ > (which corresponds to an N-state system) from one place to another.

Let quantum state $|\chi>$ = a|0>+ b|1> of a particle is to be teleported from one location to another-

Step1: Two quantum subsystems, |ϕ> and |ψ>, are prepared in an EPR entangle state. John Bell established that there are only four potential entangled states for a two-qubit quantum system, which are referred to as the Bell states (Nielson and Chuang, 2003):

$$|\Psi^+> = (|00>+|11>),\ |\Psi^->= (|00>|11>),\ |\Phi^+> = (|01>+|10>),|\ \Phi^->= (|01>|10>) \quad (27)$$

Step2: Now, we send | Φ > to sender Alice's location. Additionally, transmit |ψ> to Bob's receiver's position. These two subsystems do not yet have any information on $|\chi>$, yet they are non-causally correlated by entanglement. At this point, the two subsystems

resemble an open quantum channel that is prepared to send data.
Step3: Alice now performs a Bell state measurement on the combined system | χ>|ϕ > after bringing the teleported state | χ > into contact with the entangled state |ϕ> in order to carry out the teleportation.
Step 4: Alice uses a traditional classical communication route to provide Bob a detailed explanation of the Bell state measurement's result.
Step5: Bob's photon is in the state |ψ> = a|1>+b|0> if the result of Alice's Bell state measurement is |ϕ+>. In order to obtain an exact duplicate of the state of | χ>, Bob now knows the set of linear transformations (i.e., appropriate unitary operation) that should be done to | ψ>. Following linear transformation, the state of | χ> is now the same as it was before.
Not the particles or photons themselves, but their quantum states are destroyed and rebuilt throughout the teleportation process. Q-Teleportation Is Fundamentally Limited by Decoherence. We made the irrational assumption that Alice and Bob shared an EPR entangled pair devoid of noise or decoherence in order to make the Q-Teleportation scenarios implied. Decoherence is the process by which an object's quantum states deteriorate due to information leaking to or from the environment (also known as environmental noise) through errant interactions with the object.
Through photon loss or phonon heating, noise or decoherence can affect the quantum link (also known as the EPR interaction) between two systems. Our capacity to process quantum information is fundamentally limited by decoherence. By demonstrating that fault tolerant quantum computation is achievable, research is underway to determine whether decoherence can be minimized, avoided, or otherwise (partially or completely) eliminated (Dur and Briegel, 2003; Bashar et al., 2009).

Discussion

Einstein's goal was to illustrate that quantum mechanics was flawed, if not to refute it. Rather, he sparked a philosophical discussion that eventually validated quantum mechanics. Bell's inequality and the ERP paradox demonstrated non-locality, which supported the existence of quantum entanglement. Quantum entanglement quickly led to the development of quantum teleportation. There are numerous real-world uses for quantum entanglement and teleportation.
It is difficult to know every internal property of a quantum particle due to the no-cloning theorem and the observational collapse of superposition wave functions. Quantum teleportation is the only method that can replicate a quantum particle in its entirety. Additionally, quantum teleportation is not restricted to two particles. One trillion atoms were transported in an experiment conducted at the Niels Bohr Institute in 2006. Although this might not be sufficient to teleport a human, it does demonstrate that the number of particles that can be transferred appears to be infinite. The notion that human consciousness is a quantum phenomena is supported by Roger Penrose.
If Penrose and other proponents of this theory are right, then using quantum teleportation to make sure all of the brain's particles are in the proper state is the only effective method of transferring someone's consciousness. There are numerous uses for quantum entanglement and teleportation in dense coding and quantum computing. The manipulation of two qubits by changing the state of only one has been demonstrated by quantum entanglement. Additionally, entanglement can reduce computing time.
Instead of waiting for the two particles to interact, entanglement might be used to do the calculation quickly if two qubits are required in a quantum computer but are separated by a certain distance. Additionally, Caltech has a plan to connect two or more quantum computers via quantum teleportation to establish a quantum internet. Although teleportation and quantum entanglement may appear like theoretical concepts, they have already been demonstrated to work and will probably have a significant impact in the not-too-distant future.

CONCLUSION

Since its inception, the field of quantum teleportation has advanced remarkably. Based on the well-known idea of quantum entanglement, which Einstein referred to as "spooky action at a distance" in his EPR work, we have proposed the concept of quantum teleportation. We demonstrated that entangle particles can act as transporters, meaning that one can transfer the attributes of one entangle particle to another by adding a third message particle to it.
We have shown that with current technology, information can be transferred a certain distance. In order to assist computer scientists and engineers in moving forward in the realm of quantum key distribution, this seminar has attempted to create a basic framework for utilizing teleportation in the system.

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