

Superluminal quantum communication by using local discrimination of quantum measurements without assistance of classical information

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In this paper, two novel schemes for teleportation and quantum secure direct communication are proposed by using a new method for local quantum measurement discrimination (LQMD) (Laser Phys. Lett. 22 (2025) 125211). In the two schemes, two space-like separate observers (Alice and Bob) share two and N encoding-decoding sets (EDSs) respectively, each EDS consisting of 30 eight-qubit GHZ states and there is no classical channel between Alice and Bob. It is shown that, if Alice and Bob agreed in advances that one of them (*e.g.* Alice) should measure her qubits via two types of measurements before an appointed time T , and Bob measures his qubits and uses probability comparison method at the time T , two schemes can be completed without help of classical channel. This means that the superluminal quantum communication can be realized by using the LQMD.

Introduction

Quantum entanglement is one of the striking features of quantum mechanics. Entangled systems are thus important resource for many quantum information processing schemes including quantum computation and quantum communication (1). One of the remarkable exhibitions of entanglement is quantum teleportation (QT)(2), first proposed by Bennett *et al.*, in which an unknown quantum state can be transmitted from a sender (Alice) to a receiver (Bob) with the assistance of a prior shared Einstein-Podolsky-Rosen (EPR) pair and two bits of classical information. In the last decade, another significant application of quantum entanglement, namely quantum secure direct communication (QSDC) (3-5), is proposed. Different from quantum key distribution (QKD) (6) whose object is to generate a private key between two remote parties, QSDC can transmit in the secret messages directly without creating a key to encrypt them beforehand, so it is more demanding on security. However, in the existing QT and QSDC protocols the classical channel is indispensable, because to complete the teleportation of unknown quantum state and the transmission of secret messages the senders must transmit her measurement results to the receiver over a classical communication channel.

In the past few decades, one of the central problem of quantum information theory is quantum state discrimination (1). It is well-known that two pure states cannot be perfectly discriminated unless they are orthogonal. An object closely related to quantum state discrimination is the discrimination of quantum operation, including unitary operations, quantum channels, and quantum measurements, etc. Several researches have shown that the local quantum operation can be distinguished with certainty despite their uncertain nature (7-10). For two spacelike separated parties, however, it has been shown theoretically (11-14) that since the operations at distance commute, the averages of the observables at distant site remain the same and do not depend on the operations employed by the other distant party, *i.e.*, the no-signaling constraint

holds that entanglement cannot be used for superluminal communication. For instance, consider two observers, Alice and Bob, who have a bipartite quantum system in a known state ρ . They perform local quantum projection operations, with elements $\sum_i A_{\mu i}^\dagger A_{\mu i} = I$, $\sum_j B_{vj}^\dagger B_{vj} = I$ and $[A_{\mu i}, B_{vj}] = 0$, on the subsystem respectively. If Bob is not informed that Alice got result μ , the probability that he gets v is $p_v = \text{tr}(\sum_j B_{vj} \rho B_{vj}^\dagger)$. This result does not depend on Alice's operations. Bob cannot decide that Alice did (9, 15-17). In recent work (18), we have shown that local quantum measurement discrimination (LQMD) can be completed via two different kinds of measurement, common projective measurements (CPMs) and selective projective measurements (SPMs), and numerous eight-qubit GHZ states without help of classical channel. It was shown that, if both two observers (Alice and Bob) agreed in advance that one of them (e.g. Alice) should measure her qubits before an appointed time, and the probability comparison method was used by Bob, the LQMD can be realized without assistance of classical information. This means that the no-signaling constraint can be violated by the LQMD.

In the present paper, we discuss two examples of application of the LQMD. Firstly, we proposed a QT scheme by using LQMD without assistance of classical information. Then, we presented a new scheme of quantum cryptography, called genuine quantum secure communication (GQSC), which enables the sender to transmit secret messages without help of classical channel. This paper is organized as follows. In Section 2, we review the violation of no-signaling constraint by using LQMD. The QT via the LQMD is discussed in Section 3. In Section 4, the GQSC is investigated. Section 5 contains a brief discussion and conclusion.

Local discrimination of two different kinds of quantum measurement without help of classical channel

Let us begin with a brief review the LQMD (18). Suppose that an eight-qubit GHZ state is shared by Alice and Bob,

$$|\Phi\rangle = \frac{1}{\sqrt{2}}(|00000000\rangle + |11111111\rangle)_{A_1 A_2 A_3 A_4 A_5 A_6 A_7 B}, \quad (1)$$

where qubits $A_1, A_2, \dots, A_7$ are in the possession of Alice and B belongs to Bob. Now, let Alice make two different kinds of measurement on the state $|\Phi\rangle$. In the first kind of measurement, Alice makes common projective measurements (CPMs) on her qubits $A_1, A_2, \dots$ and A_7 under the measurement basis $\{|+\rangle, |-\rangle\}$, where $|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$, $|-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$, successively. One can see that, after measurements of Alice, 128 possible final collapsed states (PFCSs) of the qubit B will always be $\frac{1}{8\sqrt{2}}|+\rangle_B$ or $\frac{1}{8\sqrt{2}}|-\rangle_B$. Now we turn to the second kind of measurement. To realize the LQMD, Alice utilizes a novel kind of projective measurements, which we refer to as selective projective measurements (SPMs), with a series of single-qubit correlative measuring basis, on her qubits. Firstly, Alice measures the qubit A_1 in the state $|\Phi\rangle$ under the basis $\{|\nu^+\rangle, |\nu^-\rangle\}$, where $|\nu^+\rangle = x|0\rangle + y|1\rangle$, $|\nu^-\rangle = y|0\rangle - x|1\rangle$, x and y are real, $x^2 + y^2 = 1$, and let $x = (5/6)^{1/2}$, $y = (1/6)^{1/2}$. If measurement outcome of Alice is $|\nu^+\rangle_{A_1}$, the state of qubits $A_2, A_3, \dots, A_7$ and B will evolve as

$$|\phi_1\rangle = \frac{1}{\sqrt{2}F_1}(x|0000000\rangle + y|1111111\rangle)_{A_2 A_3 A_4 A_5 A_6 A_7 B}, \quad (2)$$

where we let $F_1 = 1$, Alice can in turn measure the qubits $A_2, A_3, \dots, A_7$ under the basis $\{|+\rangle, |-\rangle\}$. After that, the qubit B will always be in the state $\frac{1}{8\sqrt{2}}|\mu^+\rangle_B$ or $\frac{1}{8\sqrt{2}}|\mu^-\rangle_B$, here $|\mu^+\rangle = x|0\rangle + y|1\rangle$, $|\mu^-\rangle = x|0\rangle - y|1\rangle$. If measurement result of Alice is $|\nu^-\rangle_{A_1}$, the qubits $A_2, A_3, \dots, A_7$ and B will be in the state of

$$|\phi'_1\rangle = \frac{1}{\sqrt{2}F_1}(y|0000000\rangle - x|1111111\rangle)_{A_2 A_3 A_4 A_5 A_6 A_7 B}. \quad (3)$$

Then Alice measures the qubit A_2 under the measurement basis $\{|\lambda_1\rangle, |\lambda_1^\perp\rangle\}$, which is given by

$$|\lambda_1\rangle = \frac{1}{F_2}(\frac{x}{y}|0\rangle + \frac{y}{x}|1\rangle), \quad |\lambda_1^\perp\rangle = \frac{1}{F_2}(\frac{y}{x}|0\rangle - \frac{x}{y}|1\rangle), \quad (4)$$

where $F_2 = [(x/y)^2 + (y/x)^2]^{1/2}$.

As described above, we can easily find that the goal of the SPMs is as much as possible to make the qubit B collapsed into the state $\frac{1}{R}|\mu^+\rangle$ or $\frac{1}{R}|\mu^-\rangle$ after all, where R is a constant or a coefficient related to x and y . By the formulae deducing, a detailed implementation procedure for the SPM has been provided and the relation of the results of Alice's measurement and 128 PFCSs of the qubit B can be expressed as follows (18):

$$\begin{aligned} |\lambda_{m-1}\rangle_{A_m} &\rightarrow |\psi_m^\pm\rangle_B = \frac{1}{2^p T_m} |\mu^\pm\rangle_B, & (q \text{ terms}) \\ |\lambda_6\rangle_{A_7} &\rightarrow |\psi_7^+\rangle_B = \frac{1}{\sqrt{2} T_7} |\mu^+\rangle_B, & (1 \text{ term}) \\ |\lambda_6^\perp\rangle_7 &\rightarrow |\psi_7^-\rangle_B = P |\eta\rangle_B, & (1 \text{ term}) \end{aligned} \quad (5)$$

where $|\lambda_0\rangle = |\nu^+\rangle$, $T_m = F_1 F_2 \cdots F_m$, $m = 1, 2, \dots, 7$, $p = \frac{1}{2}(8 - m)$, $q = 7 - m$, and

$$F_m = [(x/y)^l + (y/x)^l]^{1/2}, \quad (6)$$

where $l = 2^{m-1}$, and let $F_1 = 1$, and $P = \frac{\sqrt{x^{254} + y^{254}}}{\sqrt{2} T_7 x^{63} y^{63}}$, $|\eta\rangle_B$ is a normalized state, which is given by

$$|\eta\rangle_B = \frac{1}{\sqrt{x^{254} + y^{254}}} (y^{127}|0\rangle - x^{127}|1\rangle)_B. \quad (7)$$

Now suppose that two space-like separated observers, Alice and Bob, share 30 eight-qubit GHZ states. Different from previous quantum operation discrimination schemes, we assume

that there is no classical channel between Alice and Bob. The 30 eight-qubit GHZ states can be given by

$$|\Phi^{(k)}\rangle = \frac{1}{\sqrt{2}}(|00000000\rangle + |11111111\rangle)_{A_1^{(k)} A_2^{(k)} A_3^{(k)} A_4^{(k)} A_5^{(k)} A_6^{(k)} A_7^{(k)} B^{(k)}}, \quad (8)$$

where $k = 1, 2, \dots, 30$, and the qubits $A_1^{(k)} A_2^{(k)} \dots A_7^{(k)}$ are in the possession of Alice and $B^{(k)}$ belongs to Bob. We assume that Alice and Bob agreed in advance that Alice should measure her qubits before an appointed time. Hence, before the agreed time t , Alice should randomly make two different kinds of measurement, CPMs or SPMs, on her qubits in the state $|\Phi^{(k)}\rangle$ ($k = 1, 2, \dots, 30$) respectively.

(1) If Alice performs the CPMs on her qubits, after Alice's measurements, all qubits $B^{(k)}$ will be in the states $\frac{1}{8\sqrt{2}}|+\rangle_{B^{(k)}}$ or $\frac{1}{8\sqrt{2}}|-\rangle_{B^{(k)}}$. At the appointed time t , Bob measures his qubits $B^{(k)}$ all in the basis $\{|0\rangle, |1\rangle\}$. After Bob's measurements, by statistics theory, the probability of all qubits $B^{(k)}$ in the state $|0\rangle$ or $|1\rangle$ will be in the ratio of one to one.

(2) If Alice's measurements are the SPMs, by mentioned above, after Alice's selective measurements, by calculation at least one qubit $B^{(k')}$ will be collapsed into the state $|\psi_7^-\rangle_B$. Then, at the appointed time t , Bob measures the qubits $B^{(k)}$ all in the basis $\{|0\rangle, |1\rangle\}$. Without loss of generality, we first discuss the situation in which only one qubit $B^{(k')}$ in the state $|\psi_7^-\rangle_B$ after Alice's measurements. As a special case, we also assume that all the other 29 qubits $B^{(k)}$ are in the states $|\psi_1^\pm\rangle_B$ after Alice's measurements and then all the 29 qubits are in the state $|0\rangle$ after Bob's measurements. In this case, by simple calculation, one can easily found that the probability of the 30 qubits $B^{(k)}$ in the state $|0\rangle$ or $|1\rangle$ will be in the ratio of 1 to $w_{(1)}$ after Bob's measurements, here $w_{(1)}$ (we call $w_{(1)}$ the discriminated parameter, DP) is given by

$$w_{(1)} = \left(\frac{x^{127}}{\sqrt{2}T_7x^{63}y^{63}}\right)^2 / [29\left(\frac{x}{8T_1\sqrt{2}}\right)^2] \approx 2.12 \quad (9)$$

It must be pointed out that, in above special case, one can easily verified that the $DP(w_{(1)})$ is the smallest. In any other case, the DP W will be greater than $w_{(1)}(\approx 2.12)$, that is $W \geq w_{(1)} =$

2.12.

As mentioned above, one can see that, at the appointed time t , Bob should measure his qubits $B^{(k)}$ all in the basis $\{|0\rangle, |1\rangle\}$. If Alice performs the CPMs on her qubits, after Bob's measurements, the probability of all qubits $B^{(k)}$ in the state $|0\rangle$ or $|1\rangle$ will be in the ratio of one to one. If Alice's measurements are the SPMs, after Bob's measurements, the probability of the qubits $B^{(k)}$ in the state $|0\rangle$ or $|1\rangle$ will be in the ratio of one to W ($W \geq 2.12$). One can notice that, the greater the DP W is, the easier it is to distinguish between the two different types of measurements. Therefore, Bob can easily distinguish that the measurements used by Alice are CPMs or SPMs in all circumstances. Thus, the LQMD is realized successfully without help of classical information. This means that our LQMD protocol may be not restricted by the no-signaling constraint.

Teleportation by using LQMD without help of classical information

Let's first briefly review the existing scheme of teleportation (e.g. Ref.(1)). Suppose that Alice wants to teleport an unknown arbitrary single-qubit state

$$|\xi\rangle_1 = \alpha|0\rangle_1 + \beta|1\rangle_1 \quad (10)$$

to Bob, with $|\alpha|^2 + |\beta|^2 = 1$, and the state shared by Alice and Bob as the quantum channel is an EPR pair

$$|\varsigma\rangle_{23} = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)_{23}, \quad (11)$$

where qubit 2 belongs to Alice and 3 to Bob. The state of whole system can be expressed as

$$|\Xi\rangle = \frac{1}{2} [|\Phi^+\rangle_{12}|\xi\rangle_3 + |\Phi^-\rangle_{12}\sigma_z|\xi\rangle_3 + |\Psi^+\rangle_{12}\sigma_x|\xi\rangle_3 + |\Psi^-\rangle_{12}(-i\sigma_y)|\xi\rangle_3]. \quad (12)$$

where $|\Phi^\pm\rangle$ and $|\Psi^\pm\rangle$ are Bell bases, which can be expressed as

$$\begin{aligned} |\Phi^\pm\rangle &= \frac{1}{\sqrt{2}}(|00\rangle \pm |11\rangle), \\ |\Psi^\pm\rangle &= \frac{1}{\sqrt{2}}(|01\rangle \pm |10\rangle), \end{aligned} \quad (13)$$

and $\sigma_i (i = x, y, z)$ is the Pauli matrix.

Let Alice employ Bell state measurement on her qubits 1 and 2 under the Bell bases $\{|\Phi^\pm\rangle, |\Psi^\pm\rangle\}$. Without loss of generality, we assume that Alice's Bell state measurement result is $|\Psi^+\rangle_{12}$, and she tells the results to Bob by classical channel, then Bob can make σ_x on his qubit 3 and the original state $|\xi\rangle$ can be recovered. The sketch of the scheme of teleportation is shown in Fig. 1.

Now we discuss the scheme of quantum teleportation by using LQMD. Assume that the state Alice wants to teleport is still in state $|\xi\rangle_1$ (see Eq.(10)). The quantum channel between Alice and Bob is still in state $|\varsigma\rangle_{23}$ (see Eq.(11)), and qubit 2 belongs to Alice and 3 to Bob. Different from previous schemes of teleportation, we suppose that there is no classical channel between Alice and Bob, instead, another quantum channel, called informing quantum channel (IQC), which consists of two encoding-decoding sets (EDSs). Each EDSs consisting of 30 eight-qubit GHZ state, which are given by

$$|G_{(i)}^{(k)}\rangle = \frac{1}{\sqrt{2}}(|00000000\rangle + |11111111\rangle)_{A_{1(i)}^{(k)} A_{2(i)}^{(k)} A_{3(i)}^{(k)} A_{4(i)}^{(k)} A_{5(i)}^{(k)} A_{6(i)}^{(k)} A_{7(i)}^{(k)} B_{(i)}^{(k)}}, \quad (14)$$

where $i = 1, 2$ and $k = 1, 2, \dots, 30$, and $A_{1(i)}^{(k)}, A_{2(i)}^{(k)}, \dots, A_{7(i)}^{(k)}$ belong to Alice and $B_{(i)}^{(k)}$ to Bob, respectively. To complete the teleportation, Alice and Bob should make three agreements beforehand as follows:

(1) The informing messages 0 and 1 are represented by two different kinds of measurement CPMs and SPMs respectively.

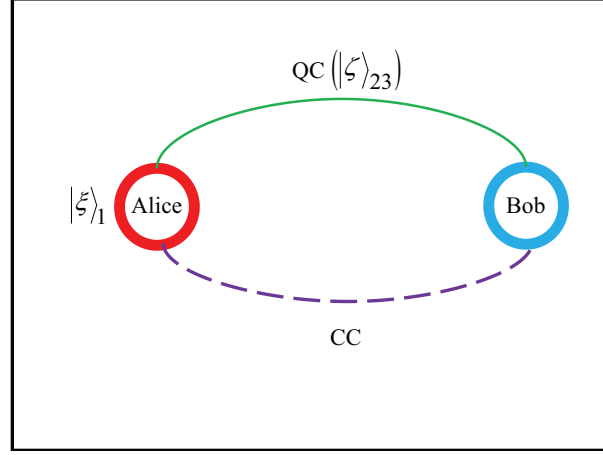


Figure 1: The sketch of the scheme for QT via a quantum channel (QC) $|\zeta\rangle_{23}$ and a classical channel (CC). Alice employs a Bell measurement on her qubits 1 and 2, then he informs Bob of the measurement result via a CC.

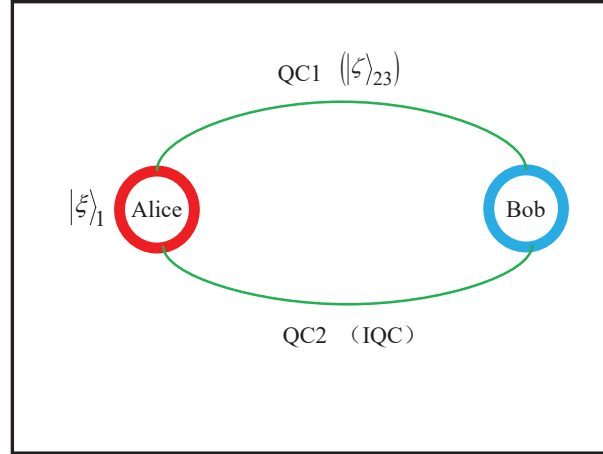


Figure 2: The sketch of the scheme for QT via a quantum channel $QC1(|\zeta\rangle_{23})$ and another quantum channel $QC2(IQC)$. Before the time T, Alice performs a Bell measurement on her qubits 1 and 2 via $QC1(|\zeta\rangle_{23})$, and encodes her measurement results on the IQC. At the time T, Bob measures in turn his qubits all in the basis $\{|0\rangle, |1\rangle\}$.

(2) The four Bell states $|\Phi^+\rangle$, $|\Psi^+\rangle$, $|\Psi^-\rangle$ and $|\Phi^-\rangle$ are represented by the informing messages 00, 01, 10, and 11 respectively.

(3) At a certain time T, Bob should check Alice's informing messages in the IQC.

Our QT scheme can be expressed as follows. Before the time T, Alice performs a Bell-state measurement on her qubits 1 and 2. Assume her result of measurement still is $|\Psi^+\rangle_{12}$, Alice encodes her informing 01 on the IQC. *i.e.*, she makes the CPMs on the set $|G_1^{(k)}\rangle$ and the SPMs on the set $|G_2^{(k)}\rangle$, successively. At the time T, Bob should check the states of qubits $B_{(i)}^{(k)}$ ($i = 1, 2$), that is, he measures in turn his qubits $B_1^{(k)}$ and $B_2^{(k)}$ all in the basis $\{|0\rangle, |1\rangle\}$. As described above, after that, Bob can extract that Alice employed the CPMs on the state $|G_1^{(k)}\rangle$ and the SPMs on the set $|G_2^{(k)}\rangle$, this means that Alice's informing messages are 01 and the result of Bell-state measurement is $|\Psi^+\rangle_{12}$. By Eq.(12), Bob knows that the qubit 3 has been collapsed into the state $\frac{1}{2}(\beta|0\rangle + \alpha|1\rangle)$, then he can perform σ_x on his qubit 3 and the original state $|\xi\rangle$ can be recovered. Thus, the teleportation is completed successfully without assistance of classical information. The sketch of our scheme of teleportation is shown in Fig. 2.

Genuine quantum secure communication by using LQMD without assistance of classical channel

Now we describe our GQSC scheme by using the LQMD. Suppose there are two remote legitimate communicators, Alice and Bob. The sender Alice wants to transmit N_0 single-bit secret classical messages (say, 100110...) to the receiver Bob. In order to encode the secret messages, Alice and Bob should agree that two different kinds of measurements, CPMs and SPMs, represent the secret messages 0 and 1 respectively. To complete this scheme, we first need to establish a secure quantum channel.

(S1) Alice prepares a large enough number M of EPR pairs in

$$|\Omega_p\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)_{A_{1(p)}B_{(p)}}. \quad (15)$$

where $M > N = 30N_0$, $p = 1, 2, \dots, M$, and takes one qubit from each EPR pair to form a qubit sequence $\{A_{1(1)}, A_{1(2)}, \dots, A_{1(M)}\}$, call the A sequence. The remaining qubits compose B sequence $\{B_{(1)}, B_{(2)}, \dots, B_{(M)}\}$. Then, Alice stores the A sequence and sends the B sequence to Bob.

(S2) To check if there eavesdropping in the line, Alice chooses a sufficiently large subset of qubits randomly in the A sequence as a checking set, call the C_A set. The remaining qubits in A sequence are reformed N ordered qubit sequences as encoding-decoding sets (EDSs) $\{A_{1(1)}^{(k)}, A_{1(2)}^{(k)}, \dots, A_{1(i)}^{(k)}\}$, call the $E_A^{(i)}$ sets, where $i = 1, 2, \dots, N_0$, $k = 1, 2, \dots, 30$.

(S3) After verifying that Bob has received all qubits of B sequence, Alice chooses randomly one of the two sets measuring bases (MBs), Z -MB $\{|0\rangle, |1\rangle\}$ and X -MB $\{|+\rangle, |-\rangle\}$, to measure the qubits in the C_A set. Then Alice publicly announces the C_A set and $E_A^{(i)}$ sets in A sequence, MB she has chosen for each qubit in C_A set and the results of her measurement.

(S4) In accordance with Alice's information, Bob takes the corresponding qubits in B sequence to form checking set C_B and the EDSs $E_B^{(i)}$. The EPR pairs composed of qubits $A_{1(i)}^{(k)}$ and $B_{(i)}^{(k)}$ can be expressed as

$$|\Omega_{(i)}^{(k)}\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)_{A_{1(i)}^{(k)}B_{(i)}^{(k)}}. \quad (16)$$

where $i = 1, 2, \dots, N_0$ and $k = 1, 2, \dots, 30$. Then Bob uses the same MB as Alice to measure the corresponding qubits in the C_B set and compares his measurement results with Alices to check the existence of eavesdropper Eve. If no eavesdropping exists, their measurement results should be completely correlated in an ideal condition. In this case, they continue to communication. Otherwise, they have to discard their communication.

Due to the method establishing quantum entanglement channel in our scheme is very similar to the previous protocols (*e.g.*, Refs. (4, 19)), the discussions on the security analysis in Refs. (4, 19) are suitable for the present protocol, so we do not repeat those discussions here further. It should be pointed out that Alice and Bob require the help of classical communication in above establishing secure quantum channel.

After insuring the security of the quantum channel, Alice should introduce six qubits $A_{r(i,j)}^{(k)}$ $r = 2, 3, \dots, 7$ with the initial state $|0\rangle$ in each EPR pair $|\Omega_{(i)}^{(k)}\rangle$ (see Eq. (16)), and perform C-NOT gates in turn on the qubits $A_{1(i)}^{(k)}$ and $A_{r(i)}^{(k)}$ $r = 2, 3, \dots, 7$ with qubit $A_{1(i)}^{(k)}$ as control qubit and $A_{r(i)}^{(k)}$ $r = 2, 3, \dots, 7$ as target qubits. After that, the EPR pairs $|\Omega_{(i)}^{(k)}\rangle$ will be transformed into N_0 EDSs, each EDSs consisting of 30 eight-qubit GHZ states, which are given by

$$|E_{(i)}^{(k)}\rangle = \frac{1}{\sqrt{2}}(|00000000\rangle + |11111111\rangle)_{A_{1(i)}^{(k)} A_{2(i)}^{(k)} A_{3(i)}^{(k)} A_{4(i)}^{(k)} A_{5(i)}^{(k)} A_{6(i)}^{(k)} A_{7(i)}^{(k)} B_{(i)}^{(k)}}, \quad (17)$$

where $i = 1, 2, \dots, N_0$ and $k = 1, 2, \dots, 30$.

Different from previous QSDC schemes (3,19-24), we suppose that, after established secure quantum channel, there is no classical channel in the following implementing quantum communication procedure. Hence, Alice and Bob need to pre-agree that, before a certain time T, Alice can encode her secret messages on the EDSs successfully, and Bob should check Alice's secret messages at the time T. Next, let us describe our GQSC scheme in detail.

Before the time T, according to her secret bit string (100110...), Alice first performs the SPMs on the EDSs $|E_{(1)}^{(k)}\rangle$ ($k = 1, 2, \dots, 30$), then performs CPMs on the $|E_{(2)}^{(k)}\rangle, \dots$, successively. At the time T, Bob should check the states of qubits $B_{(i)}^{(k)}$, that is, he measures in turn his qubits $B_{(i)}^{(k)}$ $i = 1, 2, \dots, N_0$ all in the basis $\{|0\rangle, |1\rangle\}$. After that, Bob can extract that Alice had employed the SPMs on the EDS $A_{n(1)}^{(k)}$ and there extract the bit 1, similarly, he can extract other bits, then he can obtain Alices secret messages (100110...). Thus, the GQSC has been accomplished successfully.

Discussion and conclusion

Compared with previous teleportation and QSDC schemes, the advantage in our QT is that there is no classical channel. It is just because of this, the speed of teleporting quantum information and transmitting secret classical messages is no longer limited by the speed of light, instead, it depends on the speed of quantum state collapse (or speed of quantum information) (25). In recent years, the results of some EPR experiments (25-28) set a lower bound on this speed of $10^4 \sim 10^7$ times the speed of light. Thus, the speed of teleporting an unknown quantum state in our QT scheme and transmitting secret classical messages in the GQSC scheme will be faster than the speed of light. In other words, our QT and GQSC are superluminal quantum communication schemes.

It must be pointed out that, however, our schemes of QT and GQSC are not in contradiction with the special relativity, because, in the present QT and GQSC schemes, only multipartite entangled systems were used and none of real material objects was transmitted between Alice and Bob.

Especially, transmission of secret messages in the present GQSC schemes is complete by the sender who measures her qubits of the EDSs in the quantum channel. As there is no transmission of qubits carrying the secret messages between the sender and the receiver, there is no chance for Eve to attack the secret messages in a perfect quantum channel is used. So our protocol is more secure. Different from previous QSDC schemes, the transmission of secret messages in the present GQSC does not require the help of classical channel. As there are no public information from classical communication as described in previous QSDC schemes (*e.g.* 3, 19-24), the outsiders cannot know whether the quantum communication is in progress. Thus, the present GQSC is more covert. As mentioned above, our GQSC is a genuine QSDC scheme.

In conclusion, in this paper, we first briefly review the violation of no-signaling constraint

by using the LQMD. As two applications, we presented two schemes for the teleportation of an arbitrary single-qubit state and the GQSC in which the secret classical messages can be transmitted by using LQMD without assistance of classical information. This means that the superluminal communication can be completed by using the LQMD.

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