J. At. Mol. Sci.
doi: 10.4208/jams.061310.071210a

Vol. **1**, No. 4, pp. 352-368
November 2010

Symmetric remote two-qubit preparation via positive operator-valued measure

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Received 13 June 2010; Accepted (in revised version) 12 July 2010
Published online 2 August 2010

Abstract. We present a novel tripartite scheme for remotely preparing an arbitrary two-qubit state with two three-qubit entanglements. By using a proper positive operator-valued measure (POVM), it is shown that the remote two-qubit preparation can be realized in either distant ministrant's place in a probabilistic manner via their collaboration. We also explore its applications to six special ensembles of state in detail. The extensive investigations show that the remote preparation can be achieved with higher probability provided that the prepared state belongs to the six special ensembles.

PACS: 03.67.Hk, 03.67.-a, 03.65.-w

Key words: remote state preparation, three-qubit entanglement, positive operator-valued measure, unitary operationd

1 Introduction

Applying the theory of quantum mechanics in the field of information, many interesting developments have been produced in last decades [1–15], such as quantum teleportation [1], quantum dense coding [2], quantum secret sharing [3], remote state preparation [4], and so on. Quantum teleportation was first proposed by Bennett *et al.* [1] in 1993. It is a method for interchanging quantum resources between different places. In 2000 Lo [4] formally presented another interesting novel method to transmit pure quantum states.

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It also utilizes a prior shared entanglement and some classical communication. Conventionally, this new communication protocol is termed as remote state preparation (RSP) and viewed as "teleportation of a known state". In RSP the prepared state is assumed to be completely known by the sender. In contrast, the teleported state is not required to be known by the sender in quantum teleportation. Moreover, due to the prior knowledge about the original state, to some extend the classical communication and entanglement cost can be reduced in RSP process. For an example, Pati [12] showed that for a qubit chosen from equatorial or polar great circles on a Bloch sphere, RSP requires only one forward classical bit, exactly half that of quantum teleportation. However, for general states RSP procedure requires as much communication cost as quantum teleportation. The detailed trade-off between the classical communication cost and the required entanglement in RSP procedure can be studied distinctly in the protocol proposed by Bennett *et al.* [13].

In the last decade, after Lo's pioneering work [4], RSP has attracted much attention [16–33]. Also some RSP schemes are investigated by using different entangled states as quantum channel [34–42]. In terms of entanglements in quantum channel, these RSP schemes can be classified into two types. One takes pure entangled states as the quantum channel [34–38] while the other utilizes partly pure entangled states [39–42]. In the latter case, usually people need to introduce one or more auxiliary qubits and then entangle them with his/her original qubits. By performing proper measurements on his/her qubits including the ancillas the prepared state can be collapsed to one of the eligible states. Then conditioned on the measurement results on the auxiliary qubits, the receiver performs an appropriate unitary operations on the eligible state to properly retrieve the prepared state. Note that, the so-called proper measurements are projective measurements in the latter type of existing RSP schemes [39–42]. As a matter of fact, there lies another type of measurement named positive operator-valued measure (POVM) [43], which was also called generalized measurement [44]. Since in the RSP schemes, the post-measurement state of the auxiliary system is of little interest. In contrast, the main item of interest is the probability of respective measurement results. Therefore, one may conjecture that it is quite possible to use positive operator-valued measure (POVM) [43] instead of usual projective measurement to realize RSP protocols. As a matter of fact, POVM has already attracted much attention and been employed in various quantum information processing [45–49].

However, to our best knowledge, so far there has been no proposal for remote preparation of an arbitrary two-qubit entangled state via positive operator-valued measure and three-qubit entanglements. In this contribution we show that it is indeed possible to construct such RSP protocol. That is, by using positive operator-valued measure, we propose a tripartite scheme for symmetrically preparing an arbitrary two-qubit state via two non-maximally entangled three-qubit states.

This paper is organized as follows: in Section 2, a symmetric tripartite RSP scheme is amply presented. Then its applications to six special ensembles of states are investigated in Section 3. At last, concise discussions and brief summaries are given in Section 4.