A Survey of Quantum Communication Protocols

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In this study, we focus on quantum teleportation and its extended protocols, which have developed within the broader context of quantum communication technologies such as quantum cryptography and quantum networks. In particular, we conduct a survey aimed at systematically organizing and comparing existing protocols that involve a wide variety of design elements. Many existing survey papers in the field of quantum communication primarily focus on overviews of the technology or its potential applications, while discussions that delve into the concrete structures and characteristics of individual communication protocols remain insufficient. Especially in the case of quantum teleportation–based schemes, numerous protocols have been proposed that differ in various aspects, including the number of qubits used, the structure of the quantum channel, the types of measurement bases, and the number of participating agents. However, to the best of our knowledge, no survey has yet systematically organized and compared these differences.

This situation makes it difficult for researchers to obtain a comprehensive understanding of existing knowledge or to use prior work as a reference when designing new protocols. To address this issue, we systematically collected and organized existing studies on quantum teleportation and its extended protocols. Specifically, we investigated protocols such as standard quantum teleportation, controlled quantum teleportation, bidirectional quantum teleportation, asymmetric bidirectional quantum teleportation, and cyclic quantum teleportation. From these protocols, we extracted key design elements, including communication patterns, the number of agents involved, the types of quantum channels, the number of qubits constituting the quantum channels, and the types of measurement bases.

By organizing this information according to a unified set of criteria, we constructed a data table comprising 102 quantum teleportation and teleportation-based protocols. Using this data table, we analyzed trends over time in protocol proposals, relationships between the number of agents and protocol types, tendencies in the number of controllers in controlled protocols, and the relationship between protocol types and quantum channel structures. Furthermore, focusing on cyclic protocols, we examined the applicability of cluster states as quantum channels and evaluated their resource efficiency.

As a result, we revealed that while research on quantum teleportation has concentrated on specific communication patterns and quantum channel structures, there exist design regions that are theoretically feasible but have not yet been examined in detail. The data table constructed in this study provides a foundation for a comprehensive understanding of existing protocols and serves as a guideline for future design and theoretical investigation of quantum teleportation protocols.